

TECHNOLOGY DEPARTMENT

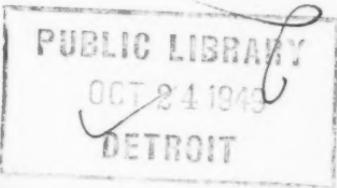
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THE JOURNAL OF
THE INSTITUTION OF
PRODUCTION ENGINEERS

VOL. XXVIII

No. 10

October, 1949



Contents :

THE GENERATION OF FINE FINISHES
BY MACHINING TECHNIQUES

by PETER SPEAR, B.Eng., Grad.I.P.E.

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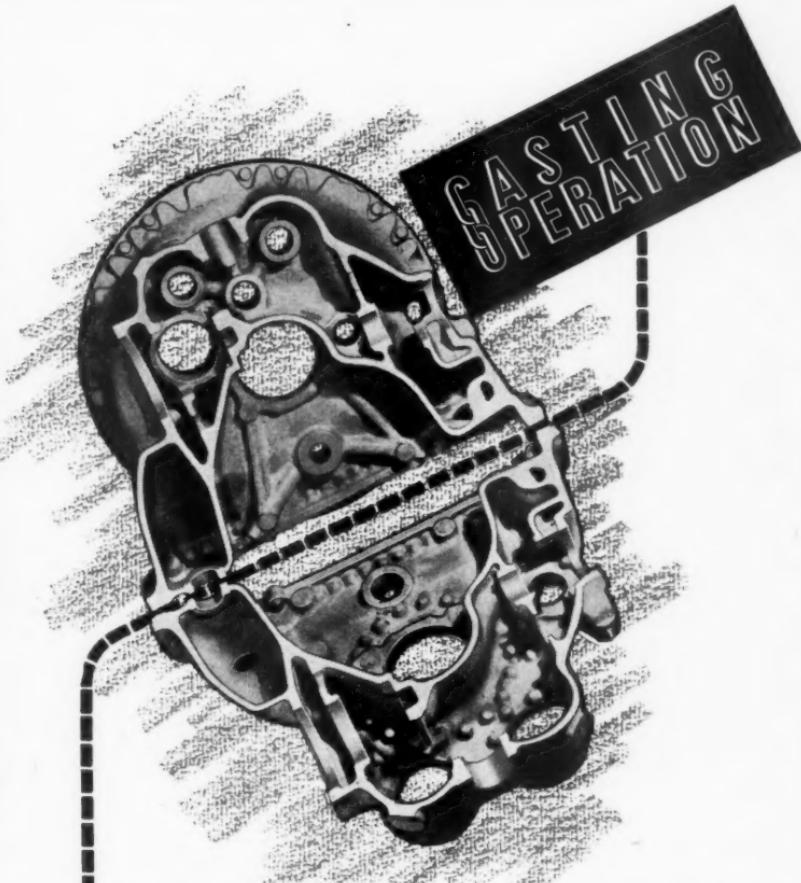
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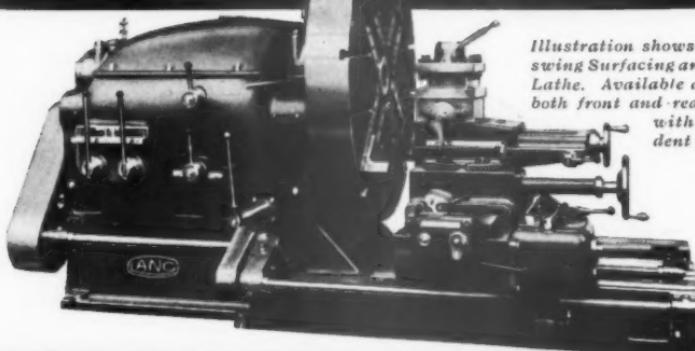


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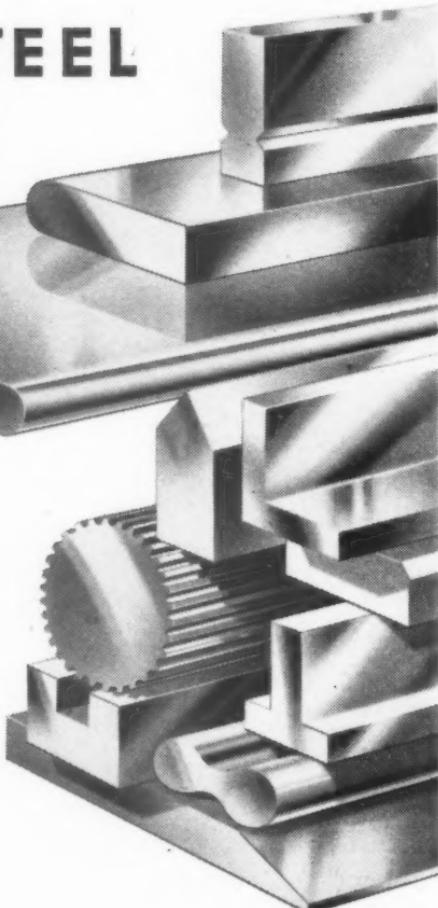
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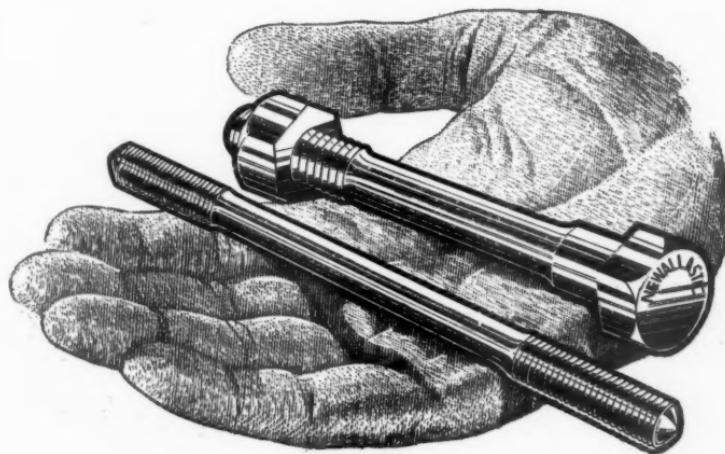
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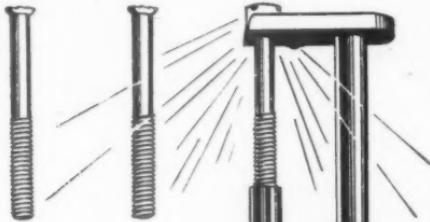
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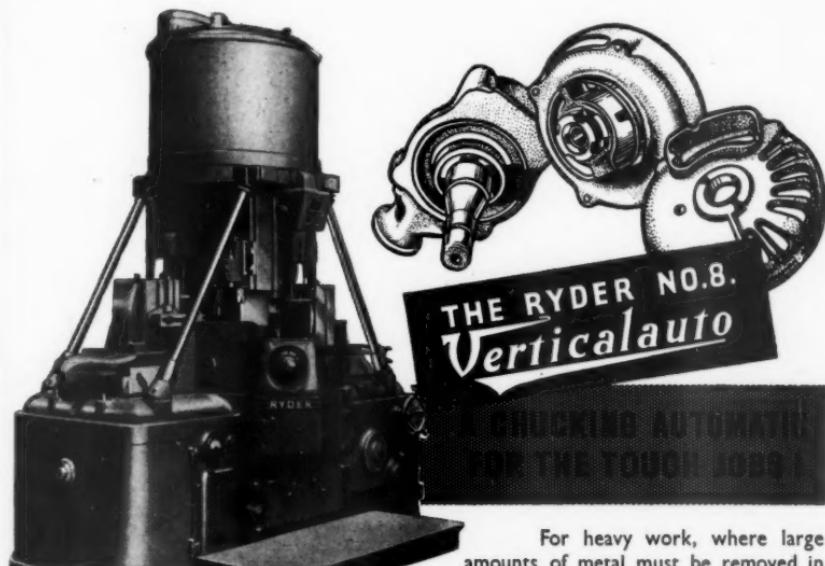
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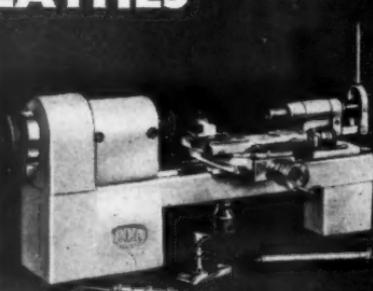
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INSTITUTION NOTES

October, 1949

SCHOFIELD TRAVEL SCHOLARSHIPS

Applications to compete for the 1950 Schofield Travel Scholarships, full details of which may be found in the September issue of the Journal, must be forwarded to the Head Office by not later than 15th October, 1949.

MEETING OF COUNCIL The next Meeting of Council will be held on Friday, October 21st, 1949, at 11 a.m., at 36 Portman Square, London, W.1.

INSTITUTION MEDALS During the years 1939 to 1944 it was not possible, owing to conditions then obtaining, to present Institution Medals for Best Papers by members and non-members. Arrangements are now in hand for these awards to be made, but unfortunately all records of the years 1939-40 and 1940-41 were lost in the fire which destroyed Headquarters in 1944.

It would be greatly appreciated, therefore, if prizewinners during this period would contact Head Office, giving particulars of the paper for which the award was made.

HONOURS The Institution is pleased to record that Mr. J. Onions, M.I.P.E., was awarded the M.B.E. in the recent Birthday Honours.

COVENTRY SECTION CONFERENCE A One-Day Conference on "Material Handling" is being arranged by the Coventry Section, to take place on June 10th, 1950. The venue will be the Humber Factories at Coventry, where all types of material handling applications will be studied at first hand.

NEWS OF MEMBERS

Mr. F. Barlow, Int. A.M.I.P.E., has been appointed Northern Sales Representative for W. E. Sykes, Staines, Middlesex.

Mr. P. A. Broadbent, A.M.I.P.E., is now Technical Assistant to the Director and Works Manager of Sterling Metals, Ltd., Nuneaton.

Mr. P. H. W. Everitt, Int.A.M.I.P.E., has been appointed Assistant Works Manager to Southern United Telephone Cables, Ltd.

Mr. W. F. Fisher, Int.A.M.I.P.E., has been promoted London Manager for Richard Sutcliffe, Ltd., of Horbury, near Wakefield.

INSTITUTION NOTES

Mr. E. Haresceugh, Int.A.M.I.P.E., has recently accepted an appointment with F.N.F. Ltd. (Textile Engineers), Burton-on-Trent.

Mr. C. W. Hawkins, A.M.I.P.E., who has been Works Manager of The Dover Engineering Works, Kent, since 1946, has been appointed a Director.

Mr. W. V. Hodgson, M.I.P.E., until recently Chief Sales Engineer to A. C. Wickman, Ltd., has been appointed General Manager, Machine Tool Division.

Mr. S. Lenny-Smyth, A.M.I.P.E., is now Works Manager of Perry Chain Co., Ltd., Birmingham.

Mr. S. G. W. Lovering, Int.A.M.I.P.E., has been appointed General Manager of Ratby Engineering Co., Ltd., Desford, near Leicester.

Mr. D. B. Melton, A.M.I.P.E., A.M.I.Mech.E., has been appointed Works Manager of Auto-Klean Strainers, Ltd., Hounslow, Middlesex.

Mr. J. W. L. Russell, A.M.I.P.E., has taken up an appointment with the Sudan Plantations Syndicate Co., Ltd., of Barakat, Blue Hill Province, Sudan.

Mr. W. A. Smyth, M.I.P.E., has been appointed Director and General Manager of Henry Meadows, Ltd., Wolverhampton.

Mr. W. Thompson, Grad.I.P.E., has been appointed an Advisory Officer in the Production Efficiency Service of the Board of Trade, North-West Region.

Mr. S. H. Thurgar, Grad.I.P.E., has been appointed Production Controller at the Westinghouse Brake & Signal Co., Ltd., Chippenham, Wilts.

Mr. D. Whitehead, Grad.I.P.E., is now lecturing at St. Helens Technical College.

VISITORS Mr. William F. Paul, M.I.P.E., one of the very **FROM ABROAD** early members of the Sydney Section, is visiting the United Kingdom on holiday. He intends to take the opportunity of inspecting as many industrial concerns as possible.

Mr. Paul is Chairman of Directors, W. G. Pickrell Pty., Ltd., and Managing Director of Electric Control and Engineering, Ltd.

Another member of the Sydney Section, Mr. A. D. Abbott, M.I.P.E., is also visiting the United Kingdom in connection with the investigation of the present methods used in this country for the manufacture of small arms weapons. Mr. Abbott is Works Manager

of the Small Arms Factory, Lithgow, and may be contacted through Canberra House, 87, Jermyn Street, London, S.W.1.

OBITUARY The Institution announces with deep regret the deaths of Mr. George E. France, M.I.P.E., Chairman and Managing Director of August's, Ltd., Halifax, and Mr. H. Ison, A.M.I.P.E., Development Engineer at Tempered Springs, Ltd., Sheffield.

BOOKS RECEIVED "Newnes Engineer's Reference Book, 1949." Edited by F. J. Camm, George Newnes, Ltd., London. Price 45/- net.

"Production Efficiency Manual" by J. J. Gillespie. Pilot Press, London. Price 2/6d. net.

"Proceedings of the Conference on Pre-Stressed Concrete," arranged by the Joint Committee on Materials and Their Testing under the auspices of the Institution of Civil Engineers. Copies may be obtained from the I.C.E., Great George Street, Westminster, S.W.1. Price 7/6d. post free.

"Welding Technology" by F. Koenigsberger, Dipl.Ing., M.I.Mech.E., M.I.W., Mem.A.S.M.E. Cleaver Hume Press, Ltd., London. Price 21/- net.

In view of the interesting contribution that it can make towards economy in the use of iron and steel, welding is receiving an increasing amount of attention as an alternative means of fabrication to older established techniques such as riveting and casting.

However, before welding is generally accepted by production personnel as a complete answer to some supply and economic problems, there is a need for more complete information as to what welding can achieve and what methods are available for application in the various fields of production. Most of the literature available to date has been either of a highly specialised nature or too general to be genuinely informative.

The publication of "Welding Technology," written by F. Koenigsberger, goes a long way towards supplying this need. Avoiding over-attention to the minutiae of the processes he describes, the author succeeds in painting a very clear and comprehensive picture of the subject. Illustrations and diagrams are well chosen to support the text, and the author's experience as a lecturer at Manchester University is manifested by the eminent suitability of the book as a text-book for examinations in welding. Engineers and students alike will find it of interest and those who seek more exact details or specific information will be well served by the effective indexing and the liberal references to literature.—A. McL., M.I.P.E.

INSTITUTION NOTES

MEETING IN MINNESOTA



A photograph taken on the occasion of the Annual Dinner of The Society of Industrial Engineers held in the University of Minnesota, Minneapolis, on May 19th, 1949, when Professor T. U. Matthew, Ph.D., M.Sc., A.R.T.C., Wh.Sch., M.I.P.E., A.M.I.Mech.E., M.I.Chem.E., M.S.A.I.E., Lucas Professor of Engineering Production at the University of Birmingham, was Guest of Honour.

Professor Matthew (third from left), who has been touring American universities and major industrial plants, gave a short address on production engineering in the United Kingdom. On his left is Professor John R. Immer, Assistant Professor of Industrial Management at the University of Minnesota.

BRITISH STANDARDS The following Standards have recently been issued and are obtainable from the British Standards Institution, 28, Victoria Street, Westminster, S.W.1, at the prices quoted.

1580 : 1949. Unified Screw Threads, price 7/6d. (post free).

Mr. J. E. Baty, M.I.P.E., Chairman of the I.P.E. Standards Committee, is an independent member of the B.S.I. Committee dealing with this work.

1564 : 1949. Pressed Steel Sectional Tanks (Rectangular), price 3/- (post free).

1563 : 1949. Cast Iron Sectional Tanks (Rectangular), price 5/- (post free).

487 : 1949. Fusion Welded Air Steel Receivers, price 3/- (post free). The I.P.E. is represented on the appropriate B.S.I. Committee by Mr. J. E. Baty, M.I.P.E.

ISSUE OF JOURNAL TO NEW MEMBERS Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

IMPORTANT In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

SECTION MEETINGS

The following meetings have been arranged to take place in October and November, 1949. Where full details are not given, these have not been received at the time of going to press.

October

1st YORKSHIRE GRADUATE SECTION. A documentary film on "Mechanical Handling" will be shown at the Technical College, Bradford, at 2.30 p.m.

3rd HALIFAX GRADUATE SECTION. A film, "Distinguished Company," will be shown and an address on "Some Observations on Factory Layout" will be given by Mr. G. H. Brook, A.M.I.P.E., A.M.I.E.E., A.M.I.Mech.E., at the Huddersfield Technical College, Huddersfield, at 7.0 p.m.

3rd YORKSHIRE SECTION. A lecture on "The Adaptability of the Jig Bore Machine for use as a Production Machine" will be given by Mr. V. J. Sayers, M.I.E.D., at the Hotel Metropole, King Street, Leeds, 1, at 7.0 p.m.

4th DUNDEE SECTION. The Inaugural Meeting will be held at the Mathers Hotel, Whitehall Crescent, Dundee, at 7.45 p.m.

5th NOTTINGHAM SECTION. A lecture on "The Education of the Production Engineer" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, at the Victoria Station Hotel, Milton Street, Nottingham, at 7.0 p.m.

October—cont.

5th PRESTON SECTION. A lecture on " Mechanical Handling " will be given by Mr. F. T. Dean, M.I.Mech.E., at Clayton, Goodfellow & Co., Ltd., Atlas Iron Works, Park Road, Blackburn, at 7.15 p.m.

5th WOLVERHAMPTON SECTION. A lecture on " Metallurgical Aspects of Production Welding Processes " will be given by Dr. A. R. E. Singer at the County Technical College, Wednesbury, at 7.0 p.m.

7th COVENTRY SECTION. A lecture on " Induction Hardening—Heat Treatment " will be given by Dr. R. H. Barfield, M.I.E.E., at the Greyfriars Room, Geisha Cafe, Hertford Street, Coventry, at 7.0 p.m.

7th WEST WALES SUB-SECTION. A lecture on " The Steel Company of Wales " will be given by Mr. W. F. Cartwright, at 7.30 p.m.

10th SHEFFIELD SECTION. At the Inaugural Meeting of the Session, to be held at the Royal Victoria Station Hotel, Sheffield, at 6.30 p.m., the address will be given by Mr. M. A. Fiennes, M.I.P.E.

11th BIRMINGHAM GRADUATE SECTION. A lecture on " Production on Capstan Lathes " will be given by Mr. R. C. Fenton, M.I.P.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7.0 p.m.

11th MANCHESTER GRADUATE SECTION. A lecture on " Graduate Status—Its Responsibilities and Implications " will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, in the Reynolds Hall, College of Technology, Manchester, at 7.15 p.m.

11th WESTERN SECTION. A lecture on " How the Money Moves in a Business " will be given by Mr. T. G. Rose, M.I.P.E., M.I.Mech.E., F.I.I.A., at the Grand Hotel, Bristol, at 7.15 p.m.

13th WOLVERHAMPTON GRADUATE SECTION. A documentary film on " Mechanical Handling " will be shown at the Willenhall Evening Institute, Stafford Street, Willenhall, at 7.15 p.m.

13th BIRMINGHAM GRADUATE SECTION. A visit to Cadbury Bros., Ltd., Bourneville, has been arranged commencing at 2.0 p.m.

October—cont.

13th COVENTRY GRADUATE SECTION. A lecture on "Graduate Status—Its Responsibilities and Implications" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, in the Greyfriars Room, Geisha Cafe, Hertford Street, Coventry, at 7.15 p.m.

13th CORNWALL SECTION. A lecture on "Fundamentals of Press Tool Design" will be given by Mr. T. A. Stevens, M.I.P.E., A.M.I.Mech.E.

14th EASTERN COUNTIES SECTION. A lecture on "Design for Welding" will be given by Mr. F. Jukes, A.M.I.Mech.E., A.M.I.W., in the Lecture Hall, Electric House, Ipswich, at 7.30 p.m.

14th WESTERN SECTION. A lecture on "Activities of P.E.R.A." will be given by Dr. D. F. Galloway, B.Sc.(Hons) M.I.P.E., at T. H. & J. Daniels Canteen, Stroud, at 7.30 p.m.

17th DERBY SUB-SECTION. A lecture on "Cast Iron as an Engineering Material" will be given by Dr. H. T. Angus at the School of Art, Green Lane, Derby, at 7.0 p.m.

17th HALIFAX SECTION. A lecture on "Some Practical Aspects of Gas Turbines" will be given by Mr. T. L. Gardner at the White Swan Hotel, Halifax, at 7.15 p.m.

18th DUNDEE SECTION. A lecture on "New Industries in Scotland" will be given by Mr. C. A. Oakley, B.Sc., Ed.B., at the Mathers Hotel, Whitehall Crescent, Dundee, at 7.45 p.m.

19th BIRMINGHAM SECTION. A lecture on "Production Management Problems" will be given by Mr. M. Seaman, M.Sc., M.I.P.E., A.M.I.Mech.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, 3, at 7.0 p.m.

19th EDINBURGH SECTION. A lecture on "Joint Consultation—Some Practical Problems" will be given by Mrs. W. Raphael at a Joint Meeting with the East of Scotland Branch of the Institute of Personnel Management at the North British Station Hotel, Edinburgh, at 7.30 p.m.

19th LIVERPOOL SECTION. An Informal Discussion Evening will be held at the Exchange Hotel, Tithebarn Street, Liverpool, at 7.15 p.m.

October—cont.

19th LONDON GRADUATE SECTION. A lecture on "Graduate Status—Its Responsibilities and Implications" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, at the Institution of Production Engineers, 36 Portman Square, London, W.1, at 7.15 p.m.

20th GLASGOW SECTION. A lecture on "Material Handling" will be given by Mr. F. T. Dean, M.I.Mech.E., at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, at 7.30 p.m.

20th LEICESTER SECTION. A lecture on "The Use of Rubber as an Engineering Material" will be given by Mr. G. W. Trowbridge, B.Sc., at the Leicester College of Technology, Room 104, The Newarke, Leicester, at 7.0 p.m.

20th LONDON SECTION. The Presidential Address will be given by Mr. W. Core, M.I.P.E., at the Royal Empire Society, Northumberland Avenue, London, W.C.2, at 7.0 p.m.

20th WESTERN SECTION. A lecture on "The Metallurgist's Place in Production Engineering" will be given by Mr. E. R. Gadd, F.I.M., at the University College of the South-West, Exeter, at 7.30 p.m.

21st MANCHESTER SECTION. The Annual Dinner will take place at the Queen's Hotel, Manchester.

22nd YORKSHIRE GRADUATE SECTION. A visit to the C.I.D. Block, West Riding Constabulary, Wakefield, has been arranged, commencing at 2.30 p.m.

24th MANCHESTER SECTION. A lecture on "Recent Developments in the Glass Industry" will be given by Mr. A. M. Robertson at the College of Technology, Sackville Street, Manchester, at 7.15 p.m.

25th LUTON, BEDFORD & DISTRICT SECTION. A lecture on "Boot and Shoe Manufacture" will be given by Mr. J. H. A. Wilkins and Mr. P. Groom in the Small Assembly Room, Town Hall, Luton, at 7.0 p.m.

26th SHREWSBURY SUB-SECTION. A lecture on "Improving Bessemer Steel Quality for the User" will be given by Dr. H. A. Dickie at the Walker Technical College, Oakengates, at 7.30 p.m.

October—cont.

26th S. WALES & MON. SECTION. A lecture on "The Production Engineer—His Education and Training" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, at the South Wales Institute of Engineers, Park Place, Cardiff, at 6.45 p.m.

27th LONDON GRADUATE SECTION. A visit has been arranged to Kodak, Ltd., Wealdstone, Harrow, Middlesex, commencing at 2.0 p.m.

28th WOLVERHAMPTON SECTION. The Annual Dinner will take place at the Victoria Hotel, Wolverhampton, when an address, "Is All Well With British Industry?", will be given by Mr. Walter Higgs.

November

2nd NOTTINGHAM SECTION. A lecture on "Mechanised Mining" illustrated by sound films, will be given by Mr. J. A. Rogers at the Victoria Station Hotel, Milton Street, Nottingham, at 7.0 p.m.

2nd PRESTON SECTION. A lecture on "The Production Engineer—His Education and Training" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, at the Harris Institute, Corporation Street, Preston, at 7.15 p.m.

2nd WOLVERHAMPTON SECTION. A lecture on "The Corby Iron & Steel Works of Stewarts & Lloyds" will be given by Mr. E. A. Taylor, M.Sc., at the West Midland Gas Board Demonstration Room, Clarence Street, Wolverhampton, at 7.0 p.m.

3rd GLASGOW SECTION. An Informal Discussion Evening will be held at the Institution of Engineers and Ship-builders, 39 Elmbank Crescent, Glasgow, C.2, at 8.0 p.m.

4th WEST WALES SUB-SECTION. An "Industrial Digest" Evening has been arranged, commencing at 7.30 p.m.

7th HALIFAX SECTION. A lecture on "Efficient Production Methods Applied to Iron Founding" will be given by Mr. G. W. Nicholls, A.M.I.P.E., M.I.B.F., at Whiteley's Cafe, Westgate, Huddersfield, at 7.15 p.m.

November—cont.

7th MANCHESTER GRADUATE SECTION. A lecture on "Mechanised Foundries" will be given by Mr. Fox, at the Reynolds Hall, College of Technology, Manchester, at 7.15 p.m. This will be followed by a works visit on Saturday, 12th November.

7th YORKSHIRE SECTION. A lecture on "Metal Spraying" will be given by a representative of the Yorkshire Metal Sprayers Ltd., at the Hotel Metropole, King Street, Leeds, 1, at 7.0 p.m.

8th BIRMINGHAM GRADUATE SECTION. A lecture on "Some Aspects of the Operation of Production Control" will be given by Mr. B. E. Stokes, Grad.I.P.E., at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7.0 p.m.

8th WOLVERHAMPTON GRADUATE SECTION. A lecture on "Powder Metallurgy" will be given by Mr. H. W. Greenwood, M.Inst.Met., at the West Midland Gas Board Demonstration Room, Darlington Street, Wolverhampton, at 7.15 p.m.

9th WESTERN SECTION. A lecture on "Incentives for Production" will be given by Mr. C. L. Taylor, A.M.I.P.E., at the Concert Hall, Westinghouse Brake & Signal Co., Ltd., Chippenham, at 7.30 p.m.

10th MANCHESTER SECTION. A lecture on "Gear Shaving" will be given by Mr. B. F. Bregi at the Engineers' Club, Manchester, at 7.15 p.m.

11th COVENTRY SECTION. A lecture on "Industrial Maintenance of Machines" by Mr. R. M. Buckle, M.I.P.E., at the Greyfriars Room, Geisha Cafe, Hertford Street, Coventry, at 7.0 p.m.

12th MANCHESTER GRADUATE SECTION. A visit has been arranged to Howard & Bullough, Ltd., Globe Works, Accrington, Lancs., commencing at 10.0 a.m.

12th YORKSHIRE GRADUATE SECTION. A lecture on "Graduate Status—Its Responsibilities and Implications" will be given by Mr. T. B. Worth, M.I.P.E., M.I.Mech.E., A.M.I.E.E., Education Officer to the Institution, at the Great Northern Station Hotel, Leeds, at 2.30 p.m.

14th SHEFFIELD SECTION. A lecture on "An Innovation in the Production of Cutlery Blanks" will be given by Mr. F. R. Francis, at the Royal Victoria Station Hotel, Sheffield, at 6.30 p.m.

November—cont.

15th DUNDEE SECTION. A lecture on "Motion Study" will be given by Miss Anne G. Shaw, M.A., M.I.P.E., at the Mathers Hotel, White Hall Crescent, Dundee, at 7.45 p.m.

16th BIRMINGHAM SECTION. A lecture on "The Science of Gear Tooth Production" illustrated by films, will be given by Mr. B. F. Bregi, at the James Watt Memorial Institute, Great Charles Street, Birmingham, 3, at 7.0 p.m.

16th EDINBURGH SECTION. A documentary film on "Mechanical Handling" will be shown at the North British Station Hotel, Edinburgh, at 7.30 p.m.

16th HALIFAX SECTION. The Annual Dinner will take place at The Old Cock Hotel, Halifax, at 7.0 p.m.

16th LIVERPOOL SECTION. A lecture on "Air Operated Fixtures" will be given by Mr. C. M. P. Willcox at Radiant House, Bold Street, Liverpool, at 7.15 p.m.

16th WESTERN SECTION. A lecture on "The Shaping of Steel" will be given by Dr. C. J. Dadswell, Ingénieur E.S.F., M.I.Mech.E., at the Grand Hotel, Bristol, at 7.15 p.m.

16th MANCHESTER SECTION. A lecture on "Recent Developments in the Glass Industry" will be given by Mr. A. M. Robertson, at the Mechanics Institute, Crewe, at 7.15 p.m.

17th GLASGOW SECTION. A lecture on "Motion Study" will be given by Miss Anne G. Shaw, M.A., M.I.P.E., at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7.30 p.m.

17th LONDON SECTION. A lecture on "Modern Methods of Gear Production" will be given by Mr. B. F. Bregi at the Royal Empire Society, Northumberland Avenue, London, W.C.2, at 7.0 p.m.

17th CORNWALL SECTION. A lecture on "Tin Metal Mining" will be given by Col. Whitworth and other speakers.

18th EASTERN COUNTIES SECTION. A lecture on "Management Through Cost Control" by Mr. T. H. Nicholson, F.C.W.A., M.I.I.A., will be given in the Lecture Hall, Electric House, Ipswich, at 7.30 p.m.

November—cont.

18th N. EASTERN GRADUATE SECTION. A documentary film on "Mechanical Handling" will be shown at the Neville Hall, Westgate Road, Newcastle-upon-Tyne, 1, at 6.45 p.m.

21st DERBY SUB-SECTION. A lecture on "The Mass Production of a British Alarm Clock," illustrated by a film, will be given by Mr. E. Desmond at the School of Art, Green Lane, Derby, at 7.0 p.m.

21st MANCHESTER SECTION. A lecture on "The Effective Use of Materials" will be given by Mr. R. F. Archer at the College of Technology, Sackville Street, Manchester, at 7.15 p.m.

22nd HALIFAX GRADUATE SECTION. A lecture on "The Production of Steel and Bronze Castings for Engineering Purposes" will be given by Mr. G. L. Hancock at the Huddersfield Technical College, Huddersfield, at 7.0 p.m.

23rd BIRMINGHAM GRADUATE SECTION. An afternoon visit to B.S.A. Tools, Ltd., Mackadown Lane, Marston Green, Birmingham, has been arranged.

24th LEICESTER SECTION. A lecture on "The Jig Boring Machine as a Production Tool" will be given by Mr. V. J. Sayers, M.I.E.D., at the Leicester College of Technology, Room 104, The Newarke, Leicester, at 7.0 p.m.

24th LONDON GRADUATE SECTION. A film on "Tools for the Job" will be shown, followed by a discussion on "Cutting Tools" by Messrs. Rose, Hardwick and Faulks, at the Institution of Production Engineers, 36, Portman Square, London, W.1, at 7.15 p.m.

24th S. WALES & MON. SECTION. A lecture on "The Steel Company of Wales—Developments at Port Talbot" will be given by Mr. W. F. Cartwright at the South Wales Institute of Engineers, Park Place, Cardiff, at 6.45 p.m.

26th LONDON GRADUATE SECTION. A visit to Arthur Guinness, Son & Co., Ltd., Park Royal Brewery, London, N.W.10, has been arranged, commencing at 10.0 a.m.

29th LUTON, BEDFORD & DISTRICT SECTION. A lecture on "Arc Welding as a Production Process" will be given by Mr. K. Doherty in the Small Assembly Room, Town Hall, Luton, at 7.0 p.m.

THE INSTITUTION OF PRODUCTION ENGINEERS

November—cont.

29th **WESTERN SECTION.** A lecture on "A New Conception of Britain's Energy" will be given by Sir Claude Gibb, C.B.E., M.I.P.E., under the auspices of the Bristol Association of Engineers, at the Physics Lecture Theatre (Royal Fort) at 6.0 p.m.

30th **SHREWSBURY SUB-SECTION.** A lecture on "Corrosion of Metals" will be given by Mr. G. T. Peat at the Technical College, Shrewsbury, at 7.30 p.m.

30th **COVENTRY SECTION.** A Dance has been arranged to take place at the Masonic Hall, Coventry.

30th **COVENTRY GRADUATE SECTION.** A lecture on "The Manufacture of Ball and Roller Bearings" will be given by Mr. R. L. Tandy in Room A5, Coventry Technical College, The Butts, Coventry, at 7.15 p.m.

ELECTION OF MEMBERS

MEETING OF COUNCIL — JULY 21ST, 1949.

The following were elected to membership by Council :

As **MEMBERS** :

J. B. Arnold, F. T. Dean, W. T. Elson, M.B.E., R. Fielding, R. W. Moon, J. H. Partridge, L. Rigg, J. Ringland, G. L. Senior.

As **ASSOCIATE MEMBERS** :

G. H. Barker, E. W. Barrell, T. D. Black, J. E. Bloor, J. Butler, W. A. A. Caudle, W. A. Childerley, J. S. Claire, R. E. Clark, S. Y. Chung, V. Duke, V. Eaves, S. C. Elliott, E. A. Fairclough, G. E. Freeman, B. E. Furbank, W. Gillespie, C. F. Green, C. B. Griffiths, V. G. J. Haden, L. J. Harris, O. Harris, R. N. Hugheff, A. James, G. A. H. Jeans, W. T. Keeble, R. E. Knox, P. L. Kumar, R. Leitch, K. W. Loader, J. Longley, R. W. Mackay, T. MacQuhae, A. J. B. Martin, G. H. Moore, G. H. Pamplin, J. L. Parker, J. H. Perkins, A. L. Purdham, C. C. Richards, K. J. Roberts, A. Sellicks, D. M. Sen, A. W. Southall, B. E. Terry, E. F. Thomas, R. B. Thomson, J. W. Trickett, A. L. Waugh, B. Weaver, E. L. Williams, H. W. D. Winkworth, E. R. Wood, A. E. W. Wyndham, A. K. Zaveri.

As **INTERMEDIATE ASSOCIATE MEMBERS** :

M. B. Angus, D. B. Archer, P. B. Burns, R. W. Chalmers, H. Colbourne, J. Croswell, J. E. Fry, G. Hall, J. M. Hinstead, H. D. Hughes, J. W. Longman, A. T. Martin, J. McMahon, E. A. Morgan, D. F. Muir, S. K. Mukherjee, R. Mulholland, V. E. P. Nayar, C. Naylor, W. F. Pitts, C. R. Pratt, W. F. Stevens, C. Woods.

As **ASSOCIATES** :

D. A. Burns, W. L. Davies, A. R. Foster, D. C. George, B. A. Yashanoff.

As **GRADUATES** :

J. A. O. Akindele, N. Allen, C. M. Andrews, J. C. Ashworth, J. Austin, J. Barr, D.F.C., J. W. Barrey, W. M. R. Bell, A. K. Bhattacharya, R. M. M. Biden, F. D. H. Bollen, P. C. Bradshaw, E. Brown, P. V. Brown, R. F. Brown, R. W.

INSTITUTION NOTES

Brown, L. W. Burgess, W. R. Burrows, A. J. Capes, J. H. Chant, C. C. Chorley, E. D. Cock, E. N. Corlett, W. J. Costin, A. F. Cox, R. S. Cracknell, J. M. Crane, C. E. Cumins, C. Cussans, E. M. Davies, M. H. Dowler, A. K. Dunkley, L. F. Edmonds, W. G. Edser, T. Edwards, D. J. Elbourn, G. G. Emmerson, A. C. Evans, R. H. Farnsworth, R. C. Farr, G. A. Felton, P. C. Felton, A. E. L. Fenn, E. Fernandes, R. W. Finney, F. W. Firkins, F. G. Ford, T. McD. Fox, J. M. Gardner, A. Gilmore, M. A. Ginlay, J. F. Gray, S. A. B. Gray, E. J. Grossmith, G. P. Gummer, M. G. Guthrie, D. Gutteridge, N. Gymer, D. J. Harris, H. Haughton, R. D. Haxby, H. E. Hefford, P. Henton, C. Hill, W. T. Hines, G. P. Holden, D. R. C. Holmes, W. D. C. Huskisson, J. Isaacs, K. L. Ives, E. H. Jacobs, D. F. R. Jepp, G. N. Johnson, H. S. Jordan, P. S. Kennedy, A. Kirk, O. L. Krys, R. E. Kurzen, R. Lambert, J. S. Langford, H. R. Langrishe, J. C. Larsen, J. K. C. Lawrence, G. J. I. Leslie, C. C. Letton, K. Liquorish, R. E. Lister, J. H. Littler, H. J. Mahady, L. Martin, W. N. McCoubrey, G. McGowan, G. F. Meades, D. J. R. Merritt, H. Moore, R. J. Moore, S. N. Mukherji, T. B. Murphy, C. J. Newman, H. Nyman, M. R. Ogle, T. W. Parry, J. E. Pemberton, R. A. Powell, J. K. Priest, G. L. Prowde, L. T. Rees, W. L. Richardson, P. F. Rix, L. B. Rutter, D. H. Ryder, P. Saessau, J. A. E. Shand, R. U. Shaw, H. Shepherd, F. W. Smith, H. T. Smith, J. A. Smith, R. Smith, G. Sowden, P. J. Spooner, A. F. Sugden, E. Sullivan, G. Sri Ramma Murty, J. E. Taylor, I. A. Thomas, R. L. Timings, A. J. Tinsley, K. T. Turner, A. J. Vale, N. W. Walker, F. W. Walton, K. F. Watson, R. Weir, G. T. Wheatcroft, J. Whyte, E. Willcox, K. G. H. Williams, N. Williams, T. A. G. Williams, G. Wittenberg, E. A. Wootton, F. Yerkess.

As STUDENTS :

J. Amos, F. J. Auton, C. F. Bateman, K. L. Bhala, D. F. Bower, L. H. Boyton-Salts, K. F. Burrett, B. E. G. Clarke, E. M. Clumpas, B. Cutler, D. J. Furse, R. J. Gentle, D. H. Hall, P. A. Hawkins, P. R. Hobson, G. H. Horne, D. H. G. Lewis, D. G. Nightingale, K. J. Poulton, A. H. Reed, D. F. Reeves, C. H. Reynolds, W. C. Rowbottom, G. L. Smith, D. Snook, N. B. Sutcliffe, E. Sutton, F. Talbot, D. A. Taylor, G. Thornton, W. E. P. Tyrrell, R. J. White, D. Whittaker, J. R. Williams, D. Wood, G. J. Wyers.

AFFILIATED FIRM :

Acheson Colloids, Ltd.

CHANGE OF AFFILIATE REPRESENTATIVE :

W. E. J. Cross.

NEW AFFILIATED FIRM :

The Churchill Machine Tool Co. Ltd.

AFFILIATED REPRESENTATIVES :

H. Bottomley.

H. Christy.

TRANSFERS.

FROM ASSOCIATE MEMBER TO MEMBER :

D. H. Bramley, F. J. Burns-Morton, H. Gibson, C. E. Gossling, E. G. Holberry, K. J. Hume, J. D. Mookerjee, J. S. Paget, J. A. Porter, A. J. Thompson, H. Tomlinson, A. Wood.

FROM INTERMEDIATE ASSOCIATE MEMBER TO ASSOCIATE MEMBER :

W. H. Bazley, G. D. Beckett, M. Clegg, C. A. Currier, G. A. Daniell, J. R. Dennis, H. G. H. Dixon, H. S. Franklin, G. C. Hodson, J. J. Howard, F. R. Humphrey, T. M. Lees, H. Lister, E. Lord, J. Merkine, J. M. Rattray, H. Rickard, L. P. Simpson, H. Thacker, F. H. Weston, J. Wilson.

FROM GRADUATE TO ASSOCIATE MEMBER :

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THE GENERATION OF FINE FINISHES BY MACHINING TECHNIQUES

by PETER SPEAR, B.Eng., Grad.I.P.E. *

*Presented to the Birmingham Graduate Section of the Institution,
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With the development of mass production techniques and the ever-increasing demand for accuracy of manufacture to improve the functioning of mechanisms, the production engineer is constantly confronted with the problem of obtaining and maintaining a particular order of surface finish on machined components. Often this finish must be obtained by the selection of the machining conditions relative to the design requirements and the machines, materials and tools available.

The present paper is an attempt to describe the underlying processes that occur in finish machining operations by the action of cutting tools, and the effect and significance of the numerous variables.

The application of a simple mathematical theory¹ is described, that combined with a knowledge of the available equipment gives the engineer a reasonable opportunity of meeting the required surface finish specification for a number of machining operations.

A survey is made of recent research on finishability, mathematical theory and machining tests and a few tentative suggestions for future research are made.

The author has attempted to demonstrate that, provided due attention is given to the various factors influencing the machining operation, very high degrees of finish can be obtained and controlled using relatively simple techniques.

MACHINING In the broad sense the term "metal cutting" covers **OPERATIONS** all types of operations from grinding to heavy planing, but this paper is limited to metal cutting operations where the swarf removed is of sizable dimensions. These include turning, milling, broaching, tapping, drilling, reaming, die thread cutting, shaping and planing. Operations such as grinding, honing, superfinishing, filing, scraping and "spill-boring" are outside the common characteristic of sizable swarf and are not pertinent to the discussion.

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SPECIFICATION OF SURFACE FINISH In the past it has been common practice to specify a finish by descriptive phrases such as "fine," "good," "ground," etc., and this has led to considerable discussion and controversy. The difficulties inherent in such descriptions were particularly evident during the recent war, when many vital components were manufactured by sub-contractors unfamiliar with the customs of the main manufacturers.

With the development of instruments for measuring surface finish², and the extensive research of recent years³, it is possible to define a given surface texture by parameters and simple indices which are amply sufficient for practical purposes. In America and the Continent there have been a number of specifications including :—

1. Aeronautical Standard—AS 107A—American Society of Automotive Engineers.
2. Surface Roughness, Waviness and Lay—ASA B46.1 - 1947—American Standards Association.
3. Dessins Techniques—CNM45—Bureau de Normalisation de la Mécanique.
4. État des Surfaces. Indications d'Usinage—VSM10320—Normes de la Société Suisse des Constructeurs de Machines.

The British Standards Institution is actively considering a standard for the United Kingdom.

Moreover, modern research has shown that the functioning of many mechanisms has been improved by the control of the degree of finish. It is not, however, merely necessary to obtain a high finish, for in many instances too smooth a finish may be just as detrimental as too coarse. Lewis⁴ has explained that in practice two mating surfaces never fit exactly, but with correctly specified surfaces such maladjustments are removed by the initial wear of "running-in" periods. If the surfaces are too rough this wear will be excessively severe and if too smooth, then the initial wear will not permit the necessary refinement of fit, and failure by seizing or scoring may result.

Thus, in many instances the production engineer must produce a finish to within both bottom and top limits, and this necessitates a knowledge of the practical fundamentals involved.

SURFACE FINISH PRODUCED BY MACHINING OPERATIONS

The texture of a surface having a given numerical degree of smoothness as expressed by such a parameter as H_{ave} , differs considerably with the method of generation as shown in Fig. 1. This illustration is a "Surf-Chek" set of standards manufactured by the Surface Checking Gage Co., of the U.S.A.

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On the other hand even the finish of the various elements of a conventionally milled surface may have complex differences as discussed by Martellotti⁵.

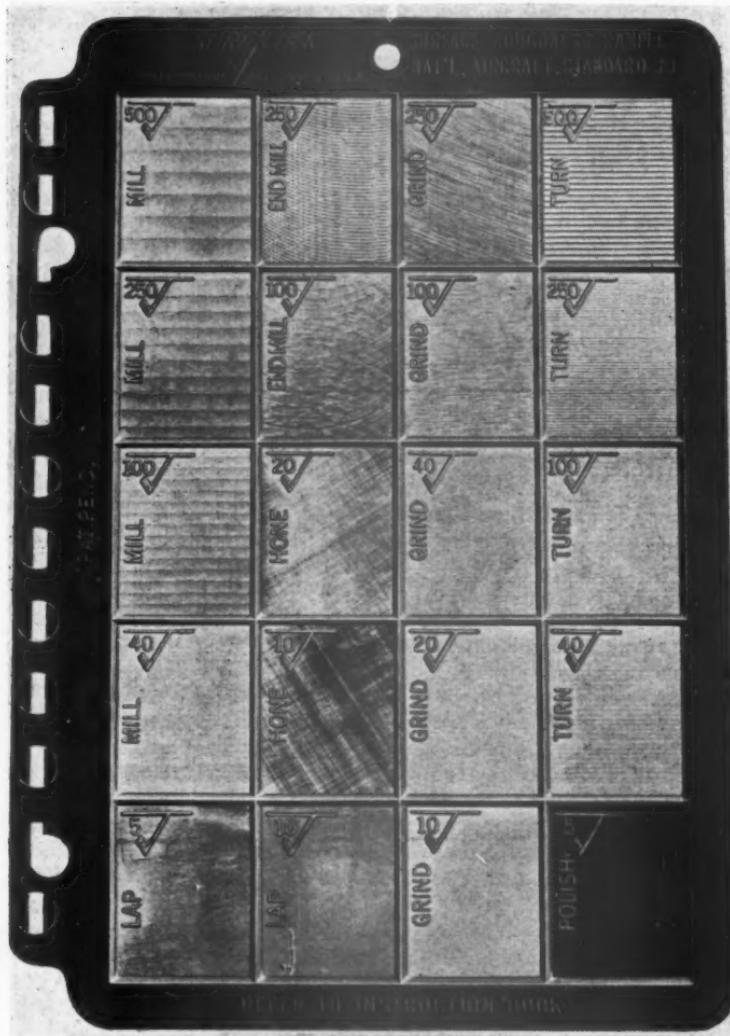


Fig. 1. Surface Finish Measuring.

NATURE OF THE METAL CUTTING ACTION All the cutting operations mentioned in this paper have the common characteristic of producing swarf of sizable dimensions. In the cutting process the basic mechanism of chip formations has been comprehensively investigated by Schwerd⁶ in Germany; by Herbert⁷ and Corker⁸ in Britain; by Ernst⁹, Zlatin and Merchant¹⁰, and Boston¹¹ in America and many other workers.

Despite the complex nature of the machining operation which is influenced by many factors as described later, three major types of chip formation have emerged, which as described by Ernst⁹ are designated :

1. Continuous chip without " built-up " edge.
2. Continuous chip with " built-up " edge.
3. Discontinuous chip.

The term " built-up " edge refers to the deformed material adhering to the top cutting face of the tool, which is intrinsically distinct from the swarf, and over which the chip slides.

Fig. 2 shows the sequence of formation of the three characteristic types of chip.

In the continuous chip, Type I, the material is compressed as it approaches the cutting edge of the tool and after passing the elastic stage becomes plastic. Flow then occurs partly along the tool face and partly upwards away from the tool face, until ultimately a plane of shear is established. As each successive element of material passes through the shear plane, sliding on the crystallographic slip-plane occurs until it is arrested by the process of work-hardening. The shear movement is then transferred to the next element of material passing through the plane of shear and the process thus forms a continuous chip which has a smooth burnished layer of highly compressed material on the side sliding in contact with the tool face. This is sometimes called a " ribbon-type " swarf formation. The surface produced on the work-piece is relatively smooth in the direction of cutting—i.e., the " lay " of the surface.

When ductile materials with high work-hardening capacities are machined, the process of swarf formation is known as Type II. The material is compressed as it approaches the cutting edge and plastic flow takes place as described before, but in this instance the resistance to relative motion between the swarf and tool face is so great that parts of the deformed chip adhere to the tool face and form a built-up edge over which the swarf then passes. The built-up edge varies rapidly in size and form as it is built up, becomes unstable, breaks down and becomes stable again. During the unstable state some fragments of built-up edge are carried along on the under-surface of the swarf, while others may become part of

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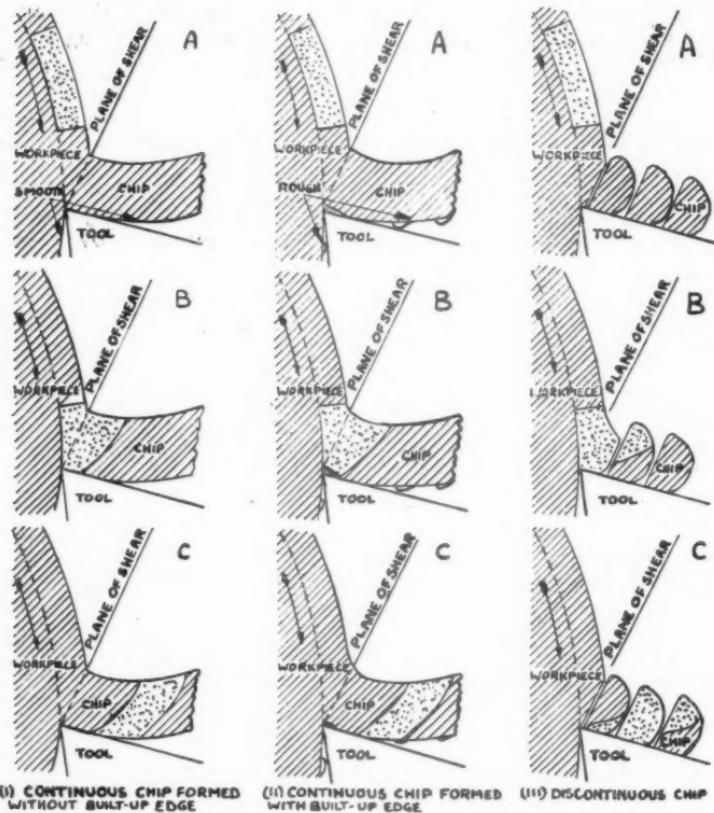


Fig. 2. The Three Types of Chip Formation.

the work-piece surface, thus giving a finish considerably coarser than that produced in the previous instance.

The discontinuous type of chip formation, Type III, is usually produced when machining brittle materials, such as cast iron or materials with deliberate inclusions to produce relatively brittle shear planes. The material approaching the cutting edge is compressed, and as it is forced along the tool face the intensity of stress ahead of the tool increases until the shear stress reaches the limiting value and rupture occurs. Repetition of this cycle creates a series of separate chip segments. This process gives a finish reasonably smooth in the direction of cutting, but is rough in the direction of feeding.

The type of the swarf characteristic depends not only on the component material but to varied extents on all the factors considered in this paper.

FACTORS INFLUENCING SURFACE FINISH There are nine major factors influencing the finish obtained in machining operations as follows :

1. The condition of the machine tool including :
 - a. Rigidity.
 - b. Accuracy of bearing clearances, spindles, etc.
 - c. Accuracy of ways and sliding surfaces.
 - d. Accuracy of screws and other controlling and adjusting elements.
2. The nature and condition of the material to be machined—i.e., its "finishability."
3. The type and condition of the cutting tool including :
 - a. General design.
 - b. Surface treatment.
 - c. Material and heat treatment.
 - d. Surface finish.
 - e. Rigidity.
4. The cutting fluid including :
 - a. General type.
 - b. Dilution or blending.
 - c. Method of application.
 - d. Rate of application.
 - e. Cooling properties.
 - f. Viscosity.
 - g. Lubricating properties.
 - h. Corrosive properties.
5. The method of swarf removal including :
 - a. Mechanical control.
 - b. Use of cutting fluid.
 - c. Use of auxiliary mechanical aids.
 - d. Special tool treatments.
6. The geometry of the cutting tool including :
 - a. Angles—in particular maximum rake angle and inclination.
 - b. Radii.
 - c. Position relative to the work-piece.
7. The depth of cut.
8. The cutting speed.
9. The feed—feed per revolution for turning tools, feed per tooth of milling cutters, the pitch of a tap, etc.

CONDITION OF THE MACHINE TOOL The condition of the machine tool is a fundamental of the fine machining operation.

The rigidity of the machine elements may be the greatest factor, as a non-rigid or, what is often neglected, a non-rigidly mounted machine can give rise to periodic vibrations which cause complicated movements of the work-piece relative to the tool, thereby damaging the machined finish by "chatter." Chatter is often associated with vibration of the tool itself as investigated by Prof. Arnold¹² for turning tools. This vibration or relative motion gives a finish distorted in various ways which usually completely obliterates the finish that would be expected from normal considerations. Chatter is a complex problem, the full analysis of the variables of which is a formidable task as yet uncompleted.

General inaccuracies of the ways and sliding surfaces, screws and other continuous elements produce a "macro" or overall variation in finish which is almost, and often completely, a geometrical change, the correction of which is relatively straightforward and the effects of which on the fine or micro finish are negligible:

FINISHABILITY OF WORK-PIECE MATERIAL The finishability of a material may be defined as that fundamental property influencing the degree of physical finish obtained by the action of a cutting tool removing swarf. A material of ideal finishability would give a surface conforming to the actual geometry and movement of the cutting tool, irrespective of the imposed machining conditions. Such a material would present a simple problem in mathematics to obtain any required degree of finish.

The finishability depends on the type and metallurgical state of the material; for example the following general observations apply to carbon steels:

1. Low Carbon Steels—best finishes are obtained by normalising or annealing followed by a light draw.
2. Medium Carbon Steels—for turning, normalising or annealing to give a pearlitic structure results in a suitable finish, but for other operations normalising or (depending on the carbide content) annealing with not more than 25% spheroidised structure is preferable.
3. High Carbon Steels—spheroidise annealed is suitable except for broaching operations, when the quenched and tempered structures are generally preferred.

It is unfortunate that though a considerable number of papers have been published on machinability and the metallurgical state of the material, little systematic attention has been given to the specific considerations of finishability.

A ferritic structure in plain carbon steels containing up to 0.3% carbon is relatively soft, ductile and easily cut with little tool wear, but because it is tough and easily deforms, it tears, adhering to the cutting edge of the tool producing excessive heating, a Type II chip formation and a relatively rough, torn surface finish.

In a gear shaping operation investigated by Wolfe¹³ the components, in a 5% nickel case hardening steel to En.37 had a finish of 60H_{ave} micro-inches and exhibited a typical "tram line" surface. The austenitic grain size on the A.S.T.M. (Timken) scale, was ten. It was found that by coarsening this to about three by heating the steel to above its austenitic grain coarsening temperature followed by air cooling and subsequent annealing, if air hardening had taken place, the finish was improved to 43H_{ave} micro-inches.

The finishability of a soft high conductivity copper is poor, whereas a drawn and cold-worked copper though harder, gives an enhanced finish. The highest degree of finishability is attained by copper containing an addition of about 0.5% of tellurium which, finely distributed in the form of tellurides gives a short relatively friable swarf and a high order of finish. In turning tests made by the author, it was found that copper containing 0.5% tellurium produced a finish of 38H_{ave} micro-inches compared with 100H_{ave} micro-inches for normal copper under identical machining conditions.

The addition of about 0.25% of lead to steels gives a fine dispersion of lead globules of sub-microscopic size which act as a lubricant between the chip and the tool, giving a continuous chip formation using less power than the non-leaded type and presenting a superior finish. The addition of sulphur to stainless steels causes the formation of sulphides which become plastic at a considerably lower temperature than that of the normal constituents. Thus a soft, easily deformed layer is formed at the chip/tool interface, forming a cushion between the swarf and the cutting face and facilitating the flow of removed metal. The effect of the additions of sulphur and lead on surface finish are shown in Fig. 3. This data was obtained from machining tests carried out by Merchant and Zlatin¹⁵, and it is obvious that the influence of suitable additions on the final finish under a given set of conditions may be considerable.

It should be noted, however, that many of the so-called "free machining" materials are not free machining for all types of operations and would be better termed "free-turning," "free-milling," etc. It is a common experience that the axial drilling of deep holes in steel bars is more easily accomplished in the normal condition than with lead additions. On the other hand the turning and milling of constructional steels is improved by the addition of lead.

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Thus the production engineer must pay particular attention to the selection and condition of the component material, to obtain the optimum finish consistent with the physical properties required by the design.

| Material | Addition | Relative Equivalent Cutting Speed f.p.m. | Relative Power Consumption H.P./Cu.In/Min. | Hardness B.H.N. | Relative Surface Finish Hrns. |
|-----------------------------------|-------------------|--|--|-----------------|-------------------------------|
| Plain 0.20% Carbon Steel | Nil | 120/140 | 0.94 | 147 | 60-70 |
| | 0.13% Lead | 160/190 | 0.57 | 170 | 30-40 |
| | 0.324% Sulphur | 210/235 | 0.60 | 170 | 25-35 |

CUTTING CONDITIONS FOR SURFACE FINISH DETERMINATIONS

Operation : Orthogonal turning.

Tool : High Speed Steel.
Top rake angle 10°
Clearance angle 3°

Speed : 95 to 110 f.p.m.

Feed : 0.003 ins. per rev.

Fig. 3. Effect of Additions of Lead and Sulphur on the Finishability of Carbon Steel.

THE CUTTING TOOL The major influence of the cutting tool, be it high speed steel, stellite, sintered carbide, ceramic or diamond is the ease with which the swarf may pass over the tool and the extent to which the clearance faces are abraded by the rubbing action between them and the component.

The mechanical finish of the tool is of fundamental importance from two considerations :

1. The finish of the cutting edges in contact with the workpiece are reproduced to some extent on its surface.
2. The finish of the tool face in contact with swarf influences the chip formation and consequently the resultant surface of the component.

Thus the cutting edges of the tool must have a high degree of finish if the final surface is to be satisfactory. There is, however, a limit to the order of this finish as ultra fine finishes may produce surfaces inferior to those generated by tools which, though slightly

rougher, have small "pits" which enable the cutting fluid to enter the seat of cutting by capillary action, consequently permitting the swarf to pass over the tool with comparative ease. It is the author's experience that little is gained by tool finishes below 4 to 8H_{ave} micro-inches for high speed steel and below 2 H_{ave} micro-inches for sintered carbide.

The ideal tool face is provided by Superfinishing or "diamond lapping" with subsequent "liquid-honing"¹⁶ to provide a controlled roughing and finally re-lapping minute lands at the actual edges of the tool.

The lower the coefficient of friction between the chip and the tool, the nearer is the approach to a Type I chip formation and consequently a better finish is obtained. The frictional forces may be reduced remarkably by the action of surface treatments as described by Wolfe and Spear¹⁷. For example, the method of oxidising given the commercial name of "Golden Arrow" considerably reduces the coefficient of friction and permits an improved swarf formation.

Fig. 4 gives an example of the effect of this treatment on $\frac{1}{8}$ " diameter drills. The lowered cutting forces are indicative of the

| TREATMENT | AVERAGE N° OF HOLES | TORQUE (lbs-in) | THRUST (lbs) |
|----------------------|---------------------|-----------------|--------------|
| NORMAL GROUND FINISH | 81 | 3.6 | 80 |
| OXIDE COATED | 136 | 2.9 | 64 |

DRILLING CONDITIONS.

TOOL: STANDARD 0.125" DIAMETER JOBBER TWIST DRILLS.

TEST MATERIAL: 0.60% CARBON STEEL OF 205 B.H.N.

SPEED: 1900 RPM.

FEED: 0.0075 INS. PER REV.

DEPTH OF HOLE: $\frac{1}{4}$ "

CUTTING FLUID: SOLUBLE OIL APPLIED IN A COPIOUS FLOOD

Fig. 4. Effect of Surface Treatment on the Cutting Efficiency of $\frac{1}{8}$ " diam. Drills.

easier swarf passage and the reduction of rubbing and build up on the lands, all of which effects tend to produce an improved finish.

The rigidity of the tool mounting is important as vibration will mar the final finish. Irrespective of the rigidity of the machine and its foundations, this vibration may be induced by interference of the tool with the previously machined surface as investigated¹² for turning.

In the milling process variations in the finish as illustrated in Fig. 5 are obtained by the compounded "run-out" of the arbor and cutter. This example demonstrates that whereas the micro finish produced by the individual teeth may be highly satisfactory, it is often found⁵ on a milled surface that the final macro finish is considerably rougher.

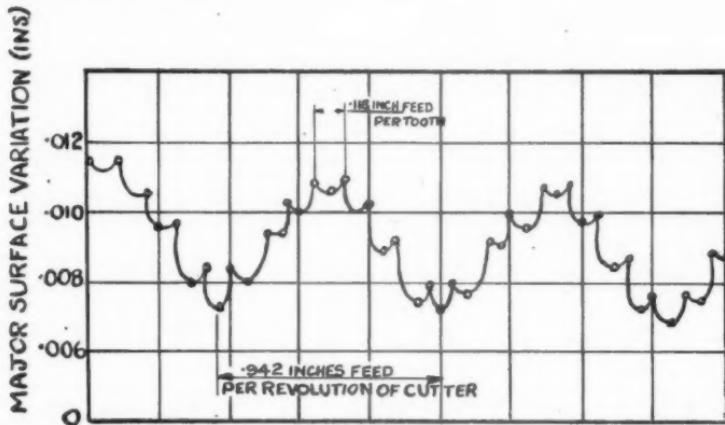


Fig. 5. Variation produced by Feed and "Arbor Run-out" on a Milled Surface.
Material : brass ; Cutter : spiral, 8 teeth, helix angle 35°, diam. 3.89" ; Speed : 38 r.p.m.; Feed ; 36" per. min.; Depth of Cut : $\frac{1}{32}$ ".

THE CUTTING FLUID The cutting fluid is probably the one fundamental variable over which the production engineer has complete control and its influence on surface finish is, particularly for ferrous materials, an important aspect of the operation.

In general the affinity or "wetting out" properties of any cutting fluid gives an excellent guide to the selection for a given material. The film formed at the "seat of cutting" provides lubrication and promotes dissociation of the metallic surfaces under the specific pressure and relative motion of the work-piece, tool and chip. It is important to note that the optimum strength of the oil film depends on the size of the cut and nature of the material being machined. If the oil film has too great a strength it acts between the

clearance faces preventing the "bite" of the tool, and though a relatively bright burnished finish is produced, it is associated with excessive tool wear and the overall size of the component becomes uncontrolled.

Soluble oils which have a specific heat of approximately 1 against that of straight cutting oils which is roughly 0.4 to 0.5 give an efficient temperature control which reduces the heat generated by the thermo-plastic properties of the work-piece.

The viscosity and not the specific heat of a cutting oil is the main factor influencing its effectiveness to remove heat in the cutting process. A thick oil forms a strong film round the tool and work-piece preventing the removal of heat in the flow of liquid. This results in excessive tool wear, though a high degree of finish may be obtained before tool failure occurs. In general, cutting oils of lower viscosity and soluble oils of higher dilutions should be employed for finishing operations and not for roughing.

The "wetting" properties of a cutting fluid may be important in finish machining operations to enable fine swarf to separate out and not be thrown against the work by the flow of cutting fluid, thus causing small scratches on the surface.

In order to obtain satisfactory finishes on high tensile steels and gas turbine alloys, the extreme pressure lubricating properties of the cutting fluid are of vital importance. This has led to the use of solid fillers such as mechanically held sulphur, zinc oxide, talc and mica in a carrier of mineral oil with additions of fatty oils. The sulpho-chlorinated types of oils as described by Stewart¹⁸ serve a similar function. The simple explanation is that these E.P. lubricating fluids provide improved lubrication at the chip/tool interface, reducing the frictional forces and hence reducing heat generation, lowering the specific pressures and tending to produce a Type I chip formation with the consequent improvement in surface finish. According to Greenhill¹⁹ the mechanism of the action of E.P. lubricant containing sulphur compounds is the formation of a chemical reaction between the sliding surface, and according to Gregory²⁰ compounds containing reactive chlorine atoms can produce on steel surfaces a film of iron chloride which has extremely good frictional properties, and which maintains these properties at very high temperatures. This would appear to be in agreement with the work of Ernst and Merchant²¹, who state that the finish of a component may be improved by reducing the coefficient of friction between the built-up edge and the tool by the introduction of an active cutting fluid which will react with the freshly cut or "nascent" chip surface to form a compound of low shear strength.

The corrosion effects of cutting fluids are important as a fine finish can be marred by minute pitting, etching and discolouration. The work of Lloyd and Beeny²² has proved of value in the

determination of the corrosion effects of soluble oil emulsions and they have devised a simple standard test—the Herbert test—for the evaluation of this property. In general, however, the corrosion effects of reputable supplies of oils are slight and are a relatively minor factor in the overall evaluation of the cutting fluid.

It is not proposed, in this paper, to give detailed recommendations of cutting fluids due to the vast variety of materials, operations and machining set-ups in the field of production engineering. Boston²³, Flynn²⁴, and other investigators have produced papers of value in their determination. Fig. 6 gives recommended types of fluids for general operations on medium tensile steels, but it should be realised, however, that these suggestions are based on considerations of finish only, and in certain instances, particularly in the case of drilling operations, tool life may be very low.

| Operation | Finish | Cutting Fluid |
|--|------------------|---|
| TURNING Capstans | Roughing | Soluble Oil 1 : 20. |
| | Finishing | Soluble Oil 1 : 25. |
| Automatics | Roughing | Sulphurised Fatty Oil. |
| | Finishing | Sulphurised Fatty Oil. |
| DRILLING General | Usual Commercial | Soluble Oil 1 : 25. |
| | High Precision | Paraffinic Mineral/Lard Oil. |
| Fine Hole Multi-spindle | High Precision | Paraffinic Mineral/Lard Oil. |
| | Usual Commercial | Soluble Oil 1 : 25. |
| Blind Hole Deep Hole | High Precision | Paraffinic Mineral/Lard Oil. |
| | Specially high | Sulphurised Mineral/Lard Oil. |
| MILLING | Usual Commercial | Soluble Oil 1 : 25. |
| | Specially high | Mineral/lard Oil + 5% Paraffin. |
| REAMING | High finish | Sulphurised Mineral/Lard Oil + 5% Paraffin. |
| | Super finish | 50% Carbon Tetrachloride/50% Vegetable Oil. |
| HONING | Super finish | Mineral turpentine. |
| LAPPING | Micro finish | Heavy Mineral Oil + suitable abrasive. |
| GRINDING External Profile thread | High finish | Light mineral blend (fat not to exceed 5%). |
| | High finish | Soluble Oil 1 : 40 (Sulpho-naphthenic acid type). |
| Profile thread Centreless | Super finish | Heavy Sulphurised Fatty/Mineral Oil. |
| | Super finish | Soluble Oil 1 : 40 (Sulpho-naphthenic acid type). |

Fig. 6. Cutting Fluids for Finish Machining Medium Tensile Steel.

SWarf REMOVAL Irrespective of the attention given to the control of the finish machining process, this effort is wasted if the finish produced is to be ruined immediately by the action of the swarf. In turning operations a "ribbon" type of swarf formation may foul the work-piece; this can be mechanically controlled by the use of "chip-breakers," suitable dimensions of which, for general steel working, are given in Fig. 7. The function of a chip-breaker is to break up the swarf into short lengths enabling the surplus material to fall away without interfering with the machined surface. A second advantage is that the short curls produced are easily removed and occupy considerably less space than the unbroken swarf.

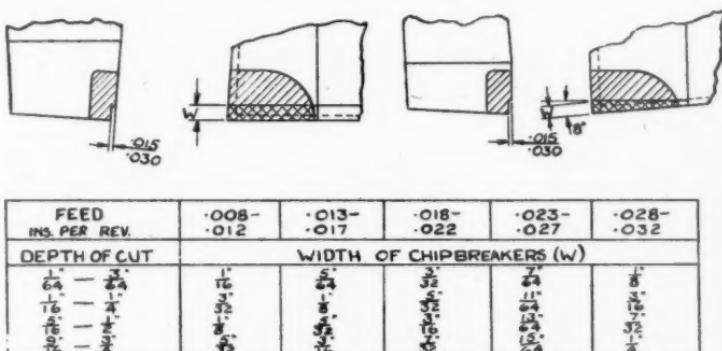


Fig. 7. Chip Breaker Dimensions.

In broaching operations, probably the main cause of poor finish and in many instances of broken broaches is that of uncontrolled swarf formation. The use of the correct hook and rake angles will produce a satisfactory swarf formation and finish but, if this swarf makes contact with the work-piece, a poor finish will result. The use of staggered "nicks" or chip-breakers on the cutting edges, as described by Carter²⁵ is imperative to produce swarf that can be easily removed by the action of the cutting fluid. Fig. 8 shows a nicked broach in operation; the machining conditions for this operation were:

Component : Flange in 40/50 ton steel to En.8. Eight splines on $4\frac{1}{8}$ " diam.

Machine : Weatherley 52" Horizontal Broaching Machine.

Speed : 2 f.p.m.

Cutting Fluid : Mineral oil with mechanically held sulphur.

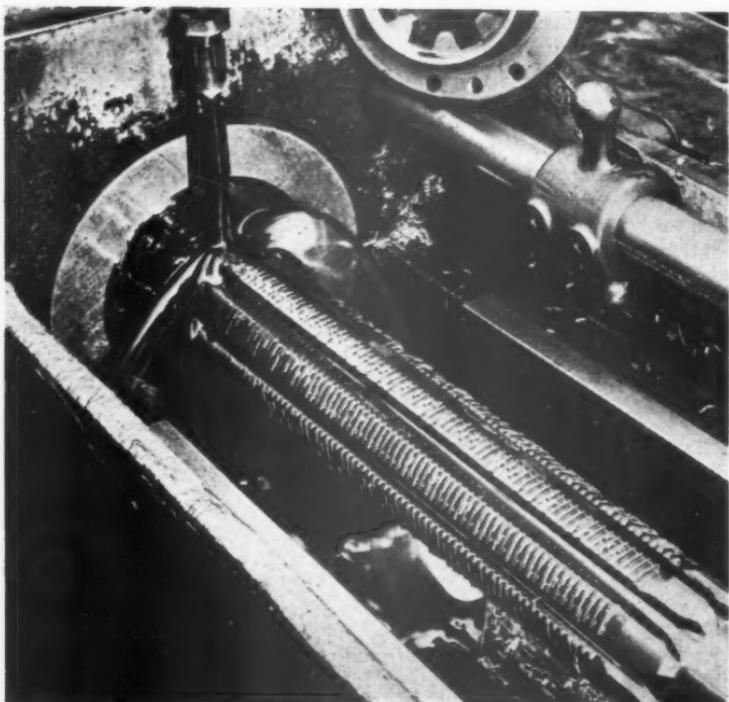


Fig. 8. Nicked Broach Measuring. (Courtesy of Messrs. Kirkstall Forge & Engineering Co. Ltd.)

In machining operations generating relatively fine swarf, the cutting fluid provides the most suitable means of swarf control, and the fluid then serves the dual function of transportation and deposition. A typical instance is barrel boring as shown diagrammatically in Fig. 9, where the cutting oil is applied to the bottom of the hole through the tool, then passing back over the tool takes the swarf to be deposited in the filters of the cutting fluid tanks. In the broaching operation of Fig. 8 it is evident that the flow of cutting oil is serving a similar function.

When used for swarf removal the cutting fluid must have reasonable "rinsing" properties so that the swarf can be separated and not held in suspension. Particles held in suspension are usually considerably harder than the component material due to the work-hardening process of swarf formation, and may give rise to pitting in turning operations and surface scores in broaching, reaming,

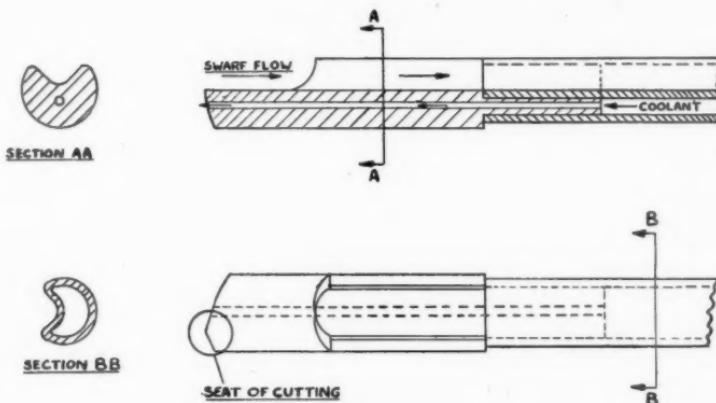


Fig. 9. Schematic Diagram of Barrel Boring, illustrating the removal of Swarf by the Cutting Fluid.

drilling, and tapping operations. Pitting and small scratches are caused by the particles being thrown on to the work-piece, and scores by them passing between the sliding faces of the tool and the component.

The use of auxiliary mechanical equipment for swarf control covers a wide range of which typical instances are :

1. Stiff brushes placed to rub over a broach removing swarf held on the teeth.
2. Magnetic filters removing small particles of ferrous swarf held in suspension in the cutting fluid.
3. The common use of rakes manipulated by hand to remove the ribbon type of swarf formation.

Swarf control may be influenced by the use of special surface treatments¹⁷ to the tool, enabling the chips to pass over the tool faces more readily than untreated tools. This is of importance in deep hole drilling operations, for example, since unless the swarf can pass up the flutes with relative ease, it will be trapped between the lands and the side of the hole with consequent scoring of the surface.

GEOMETRY OF THE CUTTING TOOL The angles of the cutting edges of a tool are important in as much as they affect the control of swarf movement and can, to some extent, influence the type of the chip characteristic. Ernst⁹, Galloway²⁶, and other workers are in general agreement that the continuous type of chip formation with no build-up which gives rise to a high degree of finish is

associated with large rake angles, whereas the continuous chip with build-up, giving a poor finish, is associated with small rake angles.

The maximum permissible rake angle is controlled by the specific cutting pressure of the work-piece for the particular operation as the greater the rake angle, the less the wedge angle and consequently the greater the tendency for the tool to fail mechanically.

In a programme of carbide face milling research undertaken by Schmidt²⁷, it was found that the surface finish was determined less by the cutter angles than by cutting speed and feed per tooth. He also demonstrated that the surface finish obtained was approximately the same for both negative and positive angles, if attention was given to the rigidity of the machining set-up and the control of swarf formation.

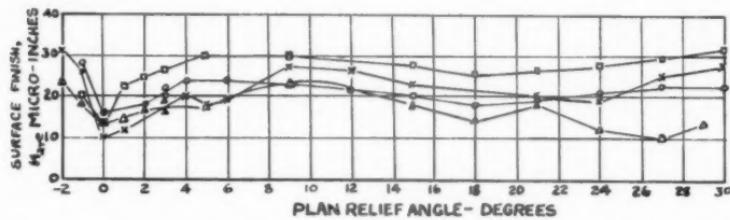
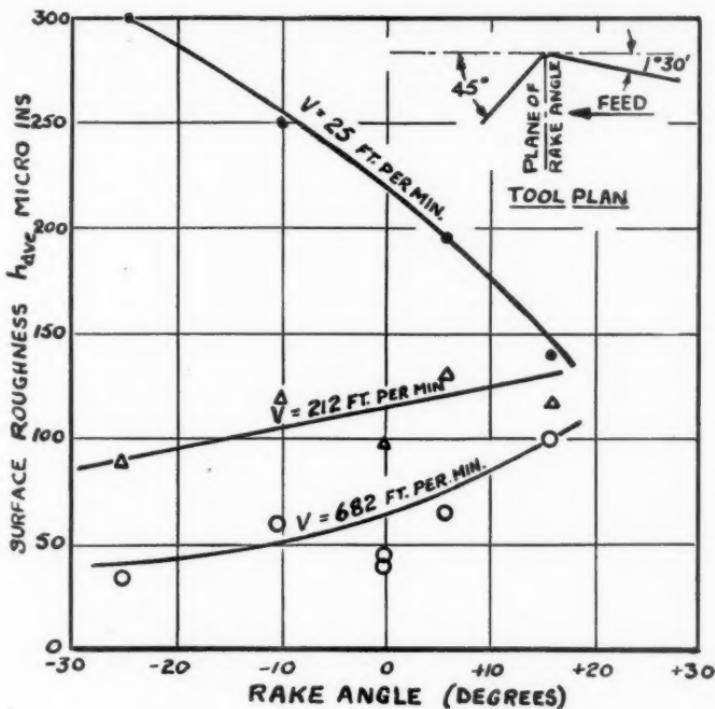


Fig. 10. Effect of Plan Relief Angle and Orientation of Carbide Tools on the Surface Finish Produced by Finish Turning.

Fig. 10 shows the effect of plan relief angle and the orientation of various carbide tools on surface finish when machining extruded aluminium. It was found²⁶ that if the tool radius was not less than 0.040" the finish was not materially affected by variation in plan relief angle (or "trail" angle) until this became less than 6°. Reduction of the angle below 6° generally improved the finish until at less than 2° a marked deterioration resulted. The effect of rake angle and cutting speed on the axial roughness of mild steel when turned with sintered carbide tools is shown in Fig. 11, which is due to Chisholm²⁸. Negative and positive angles of the order of 20° are mechanically detrimental to a carbide tool when machining mild steel, and thus for normal workshop practice the effect of rake angle variation on finish was almost within the limits of experimental error. This was not true for very low speeds, but such a speed as 25 f.p.m. for a carbide tool is within the critical range that will be described later.

The effect of nose radius when turning aluminium alloy with a carbide tool, as shown in Fig. 12 was found to be a fairly close approximation to the results expected from theory. Fig. 13 which is taken from work by Opitz and Moll²⁹ gives the influence of both



DEPTH OF CUT 0.015 INS.
 FEED PER. REV. 0.006 INS
 MATERIAL MILD STEEL
 SINTERED CARBIDE TOOLS

Fig. 11. Effect of Rake Angle and Cutting Speed on the Axial Roughness of Turned Surfaces. (Due to Chisholm).

nose radius and feed on surface roughness during the turning of steel containing about 0.50% carbon, 0.75% manganese and 0.95% chromium. The tools employed were tipped with sintered carbide and a cutting speed of 200 metres/minute was used. At this speed the chip formation was such that the surface finish corresponded with that obtained from calculation. This three-dimensional graph is typical of the careful research of these two German workers.

In tapping, broaching and reaming operations the effect of the hook angle, which corresponds to the rake angle of turning, planing and milling has an analogous effect in controlling swarf formation.

THE GENERATION OF FINE FINISHES BY MACHINING TECHNIQUES

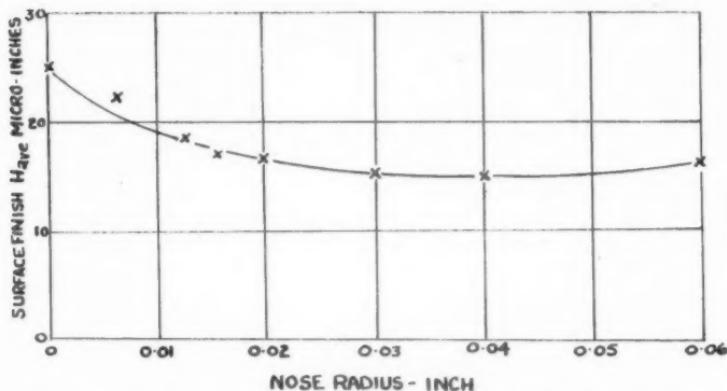


Fig. 12. Effect of Nose Radius on Surface Finish when Turning Aluminium Alloy with Sintered Carbide Tools.

In general a "shaped" flute giving a high tangential rake angle in the line of swarf flow at the cutting edge gives a high degree of finish and a fine, relatively controlled, chip formation.

One important aspect of the design of cutting tools having flutes and swarf passages is that attention must be paid to provide ample

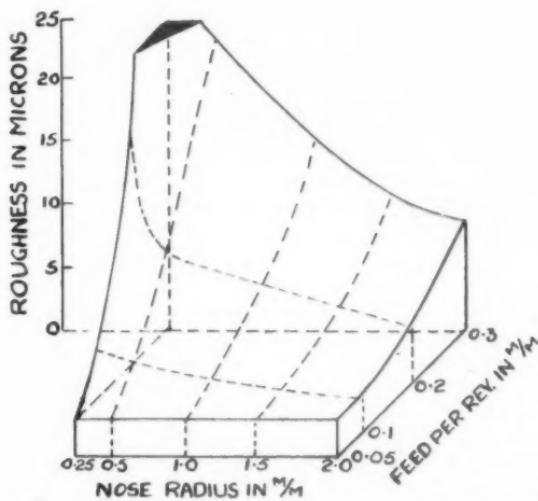


Fig. 13. Influence of Nose Radius and Feed on Surface Finish when Machining Steel. (Due to Opitz and Moll).

space to house the swarf when the tool has had a number of re-grinds. Fig. 14 gives an example of a well-designed milling cutter having reasonable swarf clearance spaces. In the work by Schmidt²⁷, it is stated that "very often a poor surface finish on the work-piece will result from chips which have become trapped underneath the



Fig. 14. Milling Cutter with Ample Swarf Space.
(Courtesy of Messrs. B.S.A. Tools Ltd).

cutter in face milling". He found that when employing negative axial rake angles on a facing cutter the chip had a tendency to curl towards the work-piece, causing scores. This was eliminated by sloping the blade radially in such a way that the chip was carried away from the machined face.

DEPTH OF CUT

Theoretically the depth of cut has no influence on the machined finish. In practice, however, the depth of cut should be sufficient to "bite" into the work-piece and, if necessary, to penetrate any previously work-hardened surface layer. It should not be increased more than 50% to 100% above this optimum for the best results, as a small depth of cut gives a good swarf formation which tends to a continuous type with no build-up.

The practical results obtained by Galloway when turning various aluminium alloys with sintered carbide tools are given in Fig. 15. It is obvious that for such alloys, the degree of finish deteriorates with increased depth of cut. For steels, particularly high tensile types, the effect is even more pronounced.

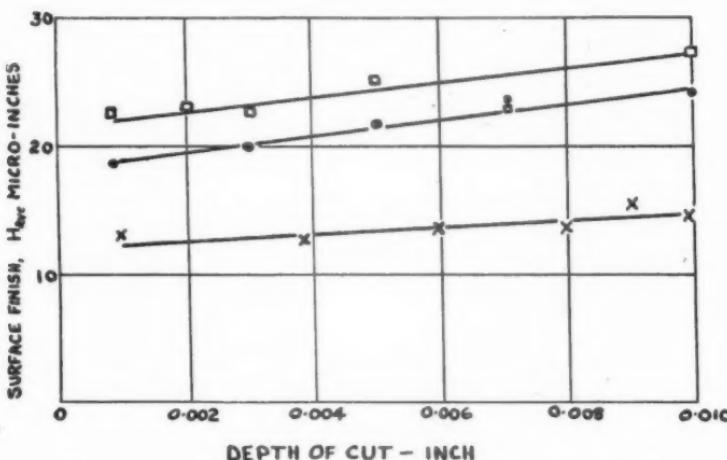


Fig. 15. Effect of Depth of Cut on Surface Finish when Turning Aluminium Alloy. (Feed: 0.005 ins. per rev).

Similarly the optimum finish is obtained in drilled holes by using fine feeds as shown for mild steel in Fig. 16 which is from work by Galloway and Morton³⁰, using drills of $\frac{3}{8}$ " diam. It will be appreciated that the feed per revolution of a drill is analogous to the depth of cut of a turning tool. In broaching operations it is common to reduce the tooth load—that is the depth of cut—of the last 5% to 10% of the teeth in order to obtain a high degree of finish. For tapping operations it is the general practice to allow the last tap of a set of three to remove about 10% to 15% of the total depth of thread.

| FEED PER REV. - INCHES | 0.002 | 0.005 | 0.008 | 0.010 | 0.014 | 0.018 | 0.023 |
|---|--------|--------|--------|--------|--------|--------|--------|
| AVERAGE OVERSIZE INCHES | 0.0047 | 0.0038 | 0.0045 | 0.0045 | 0.0044 | 0.0037 | 0.0052 |
| AVERAGE SURFACE FINISH H_{ave} MICRO-INCHES | 55 | 100 | 110 | 130 | 150 | 140 | 130 |

Fig. 16. Effect of Feed on the Accuracy and Surface Finish of Holes Drilled in Mild Steel.

THE CUTTING SPEED

The influence of cutting speed on finish has been known qualitatively for centuries, but has only been investigated within recent years. That the influence of cutting speed on surface roughness is considerable is remarkably illustrated by Fig. 17. The graph was obtained²⁸ when turning mild steel with a sintered carbide tool. A very similar shape of curve is obtained when high speed steel tools are employed, the difference being one of magnitude only. It has been reported by Field and Stansbury³² that similar curves to Fig. 17 are obtained when milling cast iron with carbide cutters.

In general, when steels are machined with high speed steel tools a high degree of finish and a continuous chip formation without build-up is obtained using cutting speeds of the order 0 to 10 f.p.m., the particular limit depending on the finishability of the component material. This is evidenced in practice by the relatively low speeds employed in the manufacture of small components for watches and other minute mechanisms and the high degree of finish obtained. Similarly, broaching and reaming operations are normally made in this range of cutting speed. This effect, also, is part of the explanation for the high degree of finish obtained in many hand operations. As the speed increases a critical stage is reached which for mild steel with high speed steel tools is about 20 to 25 f.p.m. where an extremely coarse ragged finish is obtained. Increasing the speed from this critical stage produces an improvement in finish which apparently becomes asymptotic to the theoretical value.

These general characteristics apply to almost all types of metal cutting processes and work materials, the differences being only in the value of the criteria. Notable exceptions are certain aluminium alloys where the finish was found²⁶ to deteriorate with very low and very high speeds—a complete exception to the general rule.

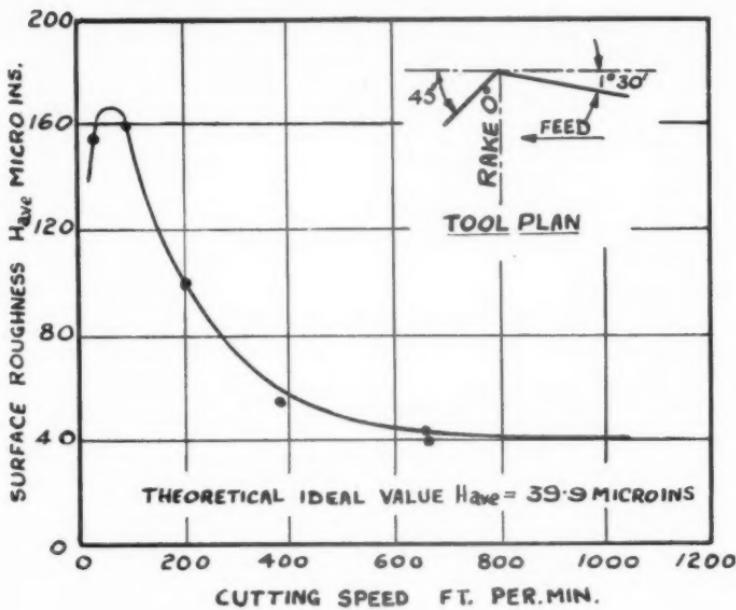


Fig. 17. Effect of Cutting Speed on Axial Surface Roughness when Turning Mild Steel with a Sintered Carbide Tool. (Due to Chisholm).

**THE EFFECT
OF FEED**

Like the depth of cut the value of the feed should be as low as possible consistent with a positive cutting and not burnishing action. To decrease a given time cycle and still maintain a given degree of finish, attention should be paid to increasing the cutting speed rather than increasing the feed.

The influence of feed on the finish obtained when turning certain aluminium alloys with diamond tools²⁰ is demonstrated in Fig. 18, where it is evident that the finish deteriorated rapidly with increase of feed per revolution. A little known fact which has been confirmed by other investigators³¹ was evident in these tests. This is that the feed of diamond tools on aluminium alloys may be as high as 0.0016" to 0.0018" per revolution without endangering the diamond or having a marked effect on surface finish.

For turning, boring and facing steels it is generally considered that the feed should not exceed 0.005" per rev. to obtain a high

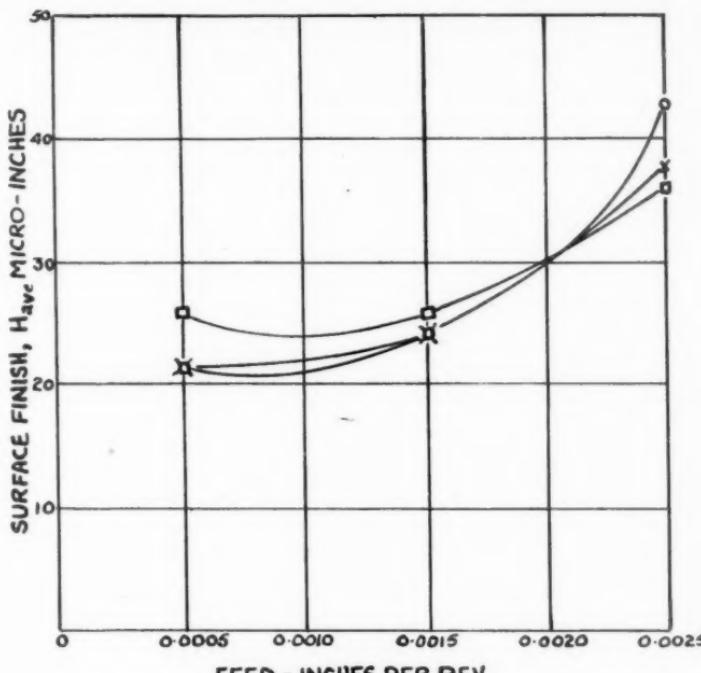


Fig 18.. Effect of Feed on the Surface Finish Obtained when Fine Finish Turning Aluminium Alloy with Diamond.

degree of finish. Feeds below 0.002" per rev. may result in a burnishing action and early tool failure due to heat generation, particularly in the case of austenitic steels. Non-ferrous materials and plastics can be machined, with certain exceptions, using feeds as low as 0.001" per rev. and even less for ultra fine finishes.

That the degree of finish obtained in milling operations²⁷ is influenced by feed more than any other factor except cutting speed is exemplified by Fig. 19. This is assuming that the influence of the cutter and arbor "run-out" is negligible, since as discussed previously, in many milling operations they are the greatest detriment to a fine finish. The cutting conditions employed were:

Speed : 428 f.p.m.

Cutter : Two bladed face milling cutter with 12° negative radial rake angle.

Test Log : Steel to SAE 4140 of 300 B.H.N.

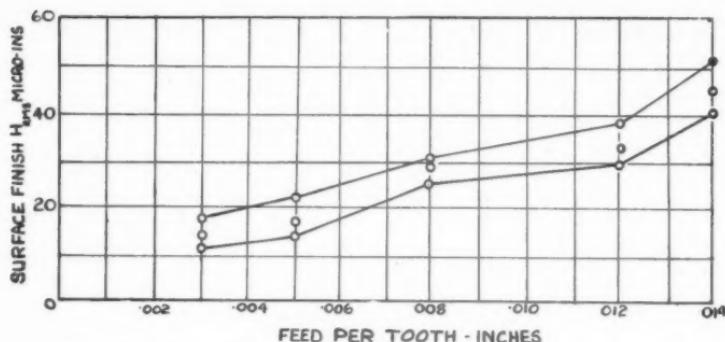


Fig. 19. Effect of Feed on Surface Finish in a Face Milling Operation.
(Due to Schmidt).

This particular work²⁷ provides evidence of the difficulty of investigating the finish machining process due to experimental variation in data. Schmidt states that "on a work-piece as small as one inch diameter it was found expedient to take three profilometer readings in different places and these very seldom were identical". It is the author's practice in research investigations to take at least ten readings and use the mean for the determination of any one surface finish value.

**MATHEMATICAL THEORY
OF FINISH MACHINING**

The object of introducing this theory into the present paper is to draw the attention of the production engineer to the use of certain relatively simple formulae which, in the author's experience, have been of great help in estimating the finish obtained by a given set of machining conditions.

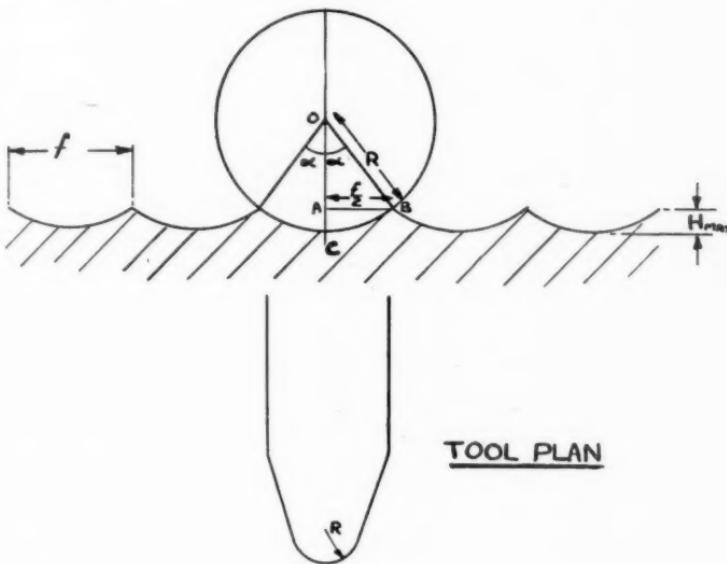
The theory is based on the reasonable assumption that the generally controlled machining variables such as the machine tool itself, the cutting fluid, the work-piece mounting, the finish of the tool and cutting speed, are adjusted so that a reasonable type of swarf formation is obtained. It is further assumed that the finish is not influenced by such extraneous causes as tool vibration or swarf fouling the component. Thus the finish is dependent on the feed and, for turning, the plan geometry of the tool.

It is appreciated that the assumptions do not necessarily hold good for many machine shop applications, but the formulae give the general order of finish and, what is often extremely helpful, the ultimate finish that can be obtained. The highest agreement between the theoretical finish and that obtained practically is shown when a continuous chip formation without build-up is produced.

The maximum height, H_{\max} , of the axial variations of the "screw thread form" produced by a turning tool of radius "R" machining at a feed of "f" per revolution is given by

$$H_{\max} = \frac{f^2}{8R}$$

as derived in Fig. 20. Curves of H_{\max} against f for various values of R are given in Fig. 21.

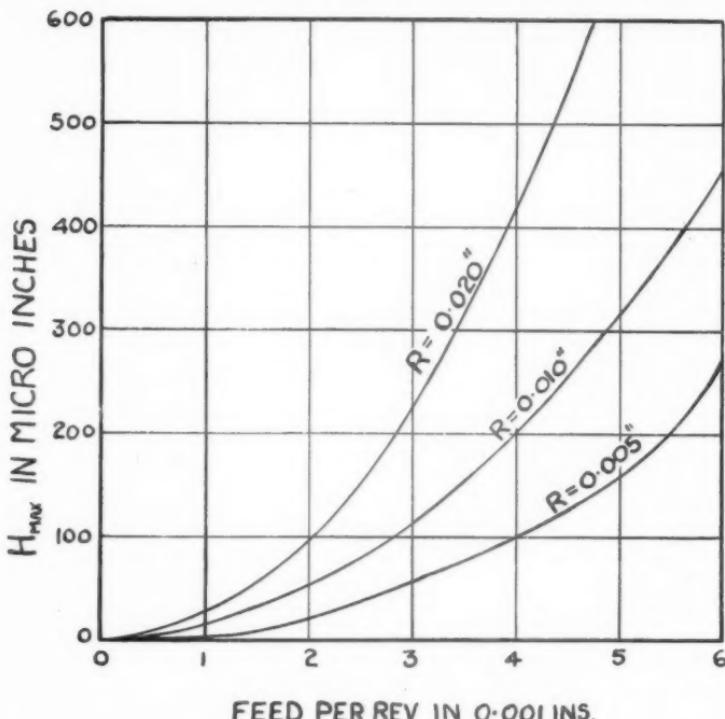


$$H_{\max} = \frac{f^2}{8R}$$

Fig. 20. Simple Radius Turning Tool Formula.

The formula also covers the shape of the undulations produced by a milling cutter in the direction of travel. In this case if "f" is the feed *per tooth* and "D" the diameter of the cutter, then

$$H_{\max} = \frac{f^2}{4D}$$

Fig. 21. Theoretical Effect of Feed on H_{max} for a Simple Radius Turning Tool

An excellent mathematical analysis of the milling process has been made⁵ where the geometrical movements of the cutter are combined with an analysis of the stress system in the workpiece to present a sound basis for the design of cutter teeth. Furthermore this work pays due attention to the nature of the finish of the workpiece.

The formula illustrated in Fig. 22, $H_{max} = \frac{f}{\cot \alpha + \cot \beta}$, applies

for a single point turning tool without a radius. In an analogous form this formula has been applied to the axial surface roughness of drilled holes, but due to experimental difficulties and machine shop variations little or no success has yet been obtained in correlating theory with practical results. Fig. 23 demonstrates the effect of feed and trail angle "β" variation on H_{max} for a tool where the approach angle is 45°.

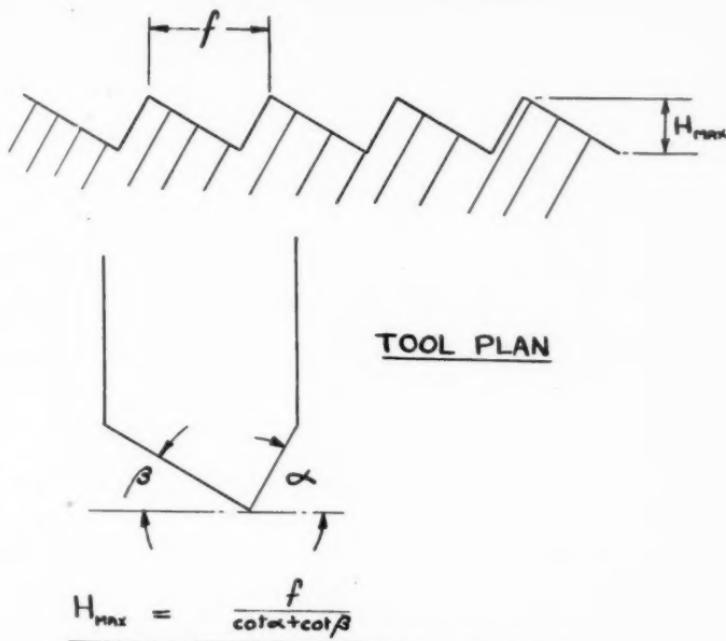


Fig. 22. Single Point Turning Tool Formula.

For a complex radius turning tool,

$$H_{\max} = f \cdot \tan \beta + \frac{R}{2} \cdot \tan^2 \beta - \sqrt{2 \cdot f \cdot R \cdot \tan^3 \beta}$$

as illustrated in Fig. 24. A complex radius turning tool is one where the feed is such that the tangential trail cutting edge assists in the removal of swarf. When the feed "f" is equal or less than $2 R \cdot \tan \beta$ the simple radius turning tool formula applies.

Fig. 25 illustrates the variation of H_{\max} against feed per revolution for various values of β .

The theoretical average height of the surface, H_{ave} , may be taken as roughly one third of the theoretical maximum height H_{\max} .

A brief study of the formulae shows that the trail angle may have a decisive influence in improving the finish of the work-piece. In practice this only applies to a relatively small number of operations, since a very small value for β is associated with considerable tool wear and a poor swarf formation. Sintered carbide, ceramic and diamond tools machining materials of good finishability can, however, with their high abrasion resistance, take advantage of such a tool design.

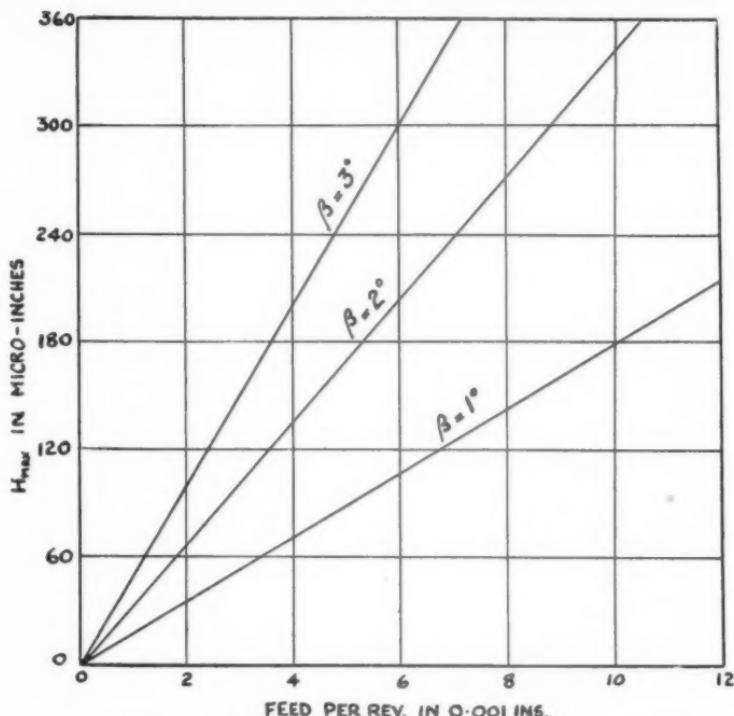
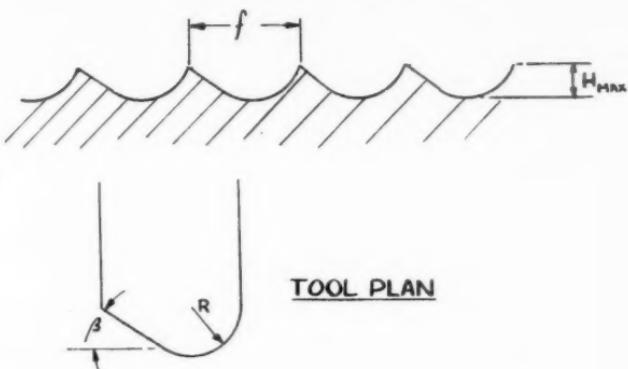


Fig. 23. Theoretical Effect of Feed and Trail Angle on H_{max} for a Single Point Turning Tool where $\alpha = 45^\circ$.

CORRELATION OF MATHEMATICAL THEORY, FINISHABILITY AND MACHINING CONDITIONS

Little quantitative work has been published in this country or America dealing with the correlation of mathematical theory, finishability and machining conditions. In Germany, however, Optiz and Moll²⁹ carried out an extensive turning research which demonstrated that for a satisfactory "set-up" the decisive influences on surface roughness were feed, tool radius, cutting speed and the properties of the work-piece. They employed the term "Cutting Degree of Merit" (Schmittgütegrad) which represents the relation between the calculated and measured roughness, and may be taken as the true finishability of the component.

When the cutting speed is such that a continuous chip without build-up is formed, they demonstrated that the influence of cutting speed disappears and the roughness is dependent on the ratio nose



WHEN $f < 2R \tan \beta$, $H_{\max} = \frac{f^2}{8R}$

WHEN $f \geq 2R \tan \beta$,

$$H_{\max} = f \tan \beta + \frac{R}{2} \tan^3 \beta - \sqrt{2fR \tan^3 \beta}$$

Fig. 24. Complex Radius Turning Tool Formula.

radius/feed per revolution. The greater the admissible ratio—that is, the higher the finishability of the work-piece—the greater the feeds and tool radii which can be employed for the same surface roughness. Tables were compiled for machine shop use by the two authors in an attempt to assist the production of surfaces with a predetermined finish under workshop conditions.

Gottschald³³ carried out work on the correlation of machining conditions, surface finish and roughness but does not appear to have paid much attention to correlating the properties of the work-piece.

Recent work by Dyachenko³⁴ has been concerned with a more complex theory for turned finishes which attempts to allow for two practical aspects not covered by the simple theory. These are :

- (1) In practice the work-piece material tends to deform plastically round the nose of the tool, resulting in a larger H_{\max} value than allowed by the simple theory.

THE GENERATION OF FINE FINISHES BY MACHINING TECHNIQUES

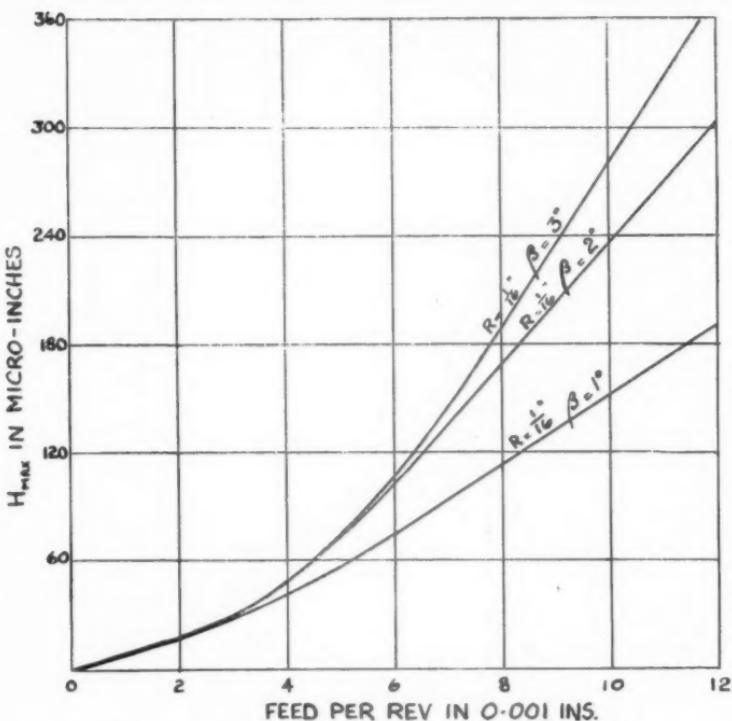


Fig. 25. Theoretical Effect of Feed on H_{max} for a Complex Radius Turning Tool.

(2) The cutting edges of the tool are not absolutely smooth, and thus tend to roughen the work-piece irrespective of the physics of the cutting action.

The value of such work is lost in practice for several reasons :

- (1) The plastic deformations relative to the theoretical finish that occur in finishing operations are small, and in rough machining, finish is of little importance.
- (2) The surface finish of the tool is considerably finer than the finish of the work-piece, since the tool finish is related to the size of the grinding wheel particles and the finish of the work-piece to the size of the tool radius.
- (3) General practical variations do not warrant the use of formulae other than to the first approximation.

RECENT FUNDAMENTAL WORK ON METAL CUTTING

Very recent work by Merchant and Zlatin¹⁵ has revealed what the author believes to be a new field for investigation of the phenomena of surface finish machining. These workers machined hollow cylinders under the conditions of orthogonal cutting illustrated in Fig. 26. Among other phenomena investigated, they studied the effect of cutting speed and feed on the

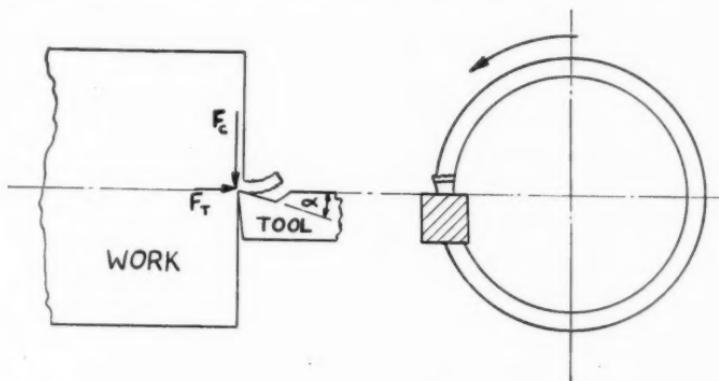


Fig. 26. Principle of Orthogonal Cutting.

coefficient of friction between the chip and the tool as illustrated in Figs. 27 and 28. The portions of the curves of these graphs relating to the lower speed range show a considerable similarity to the type of curves obtained by other workers investigating the effect of cutting speed on surface finish. Since it is appreciated generally that a high coefficient of friction is associated with a poor surface finish, these results give a remarkable mechanical explanation of the reason for the influence of cutting speed on surface finish. This may also be correlated with the fact that a cutting fluid with good lubricating properties will permit an increased cutting speed as well as producing a superior finish.

Furthermore the curves afford the interesting speculation that as the cutting speed is increased there may be, for steels, cutting speed ranges where a peak of poor finish is obtained other than that previously observed at relatively low rates. There has been no published data to prove or disprove this conjecture, but it may explain isolated machine shop problems in which for unknown reasons, poor finishes have been obtained at relatively high cutting speeds, and where increasing or decreasing the speed has provided the solution.

THE GENERATION OF FINE FINISHES BY MACHINING TECHNIQUES

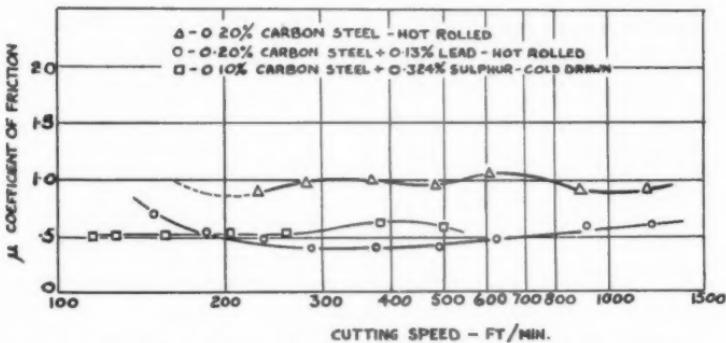


Fig. 27. Effect of Cutting Speed on the Coefficient of Friction between Chip and Tool for Carbon Steel.

In the original paper the cyclic curves shown in Fig. 27 and 28 were drawn as straight lines, but the variation, which is of the order of 20%, is sufficient, in the writer's view, to justify the present discussion.

This hypothesis may be connected with the evidence of Ulbricht³⁵ that the relationship between the width of the wear marks (B) of a turning tool and turning time (T) is a cascade as shown in Fig. 29 and not a continuous parabola as previously considered, since cutting speed, tool wear and the coefficient of friction are intimately connected with the action of the swarf passing over the face of the cutting tool.

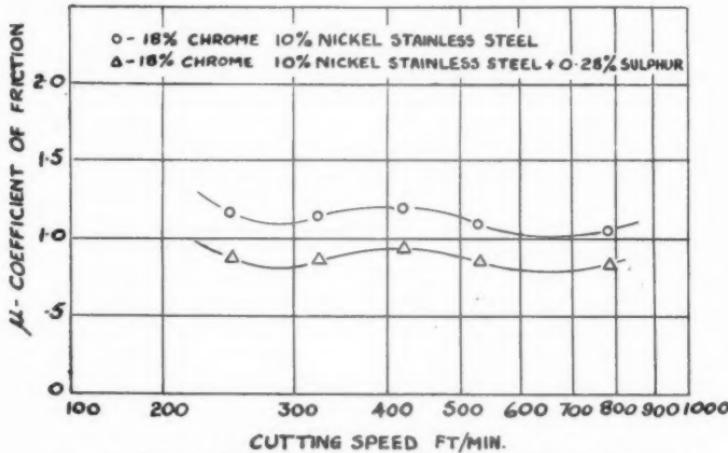


Fig. 28. Effect of Cutting Speed on the Coefficient of Friction between Chip and Tool for Stainless Steel.

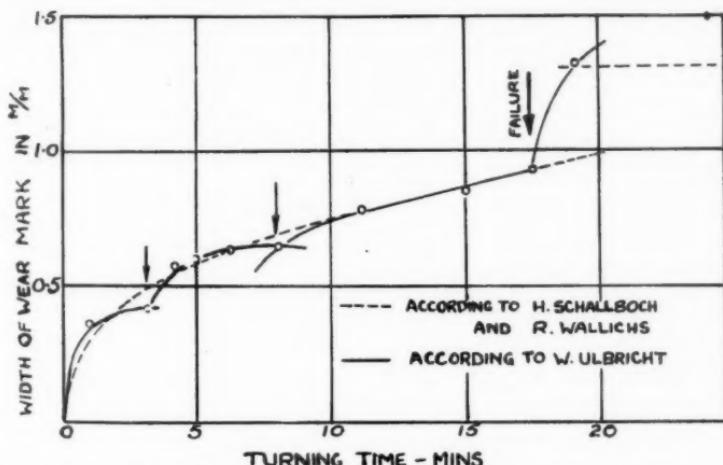


Fig. 29. Relationship between Width of Wear Mark and Turning Time.

CONCLUSIONS An attempt has been made to describe the influence of the variables of the finish machining process by the action of cutting tools. The physics of swarf formation, the effects of speed, feed, tool design, machine tool condition and the other machine shop factors on surface finish have been covered together with reference to the simple mathematical theory.

Finally, a brief review of the correlation of finishability, mathematical theory and machining conditions has been made, together with a survey of recent research developments.

The production engineer to whom falls the task of producing components with specified degrees of surface finish has to pay due attention to the fundamentals of the finish machining process, and the author trusts that this paper will give some little assistance to this end.

ACKNOWLEDGEMENTS The author wishes to thank Mr. D. A. Oliver, Director of Research to the B.S.A. Group of Companies for permission to present this paper; Mr. K. J. B. Wolfe, Head of the B.S.A. Group Machinability Research Laboratory, for help and encouragement; and Mr. E. V. L. Hughes, Research Assistant at this Laboratory for considerable help in the preparation of many of the illustrations.

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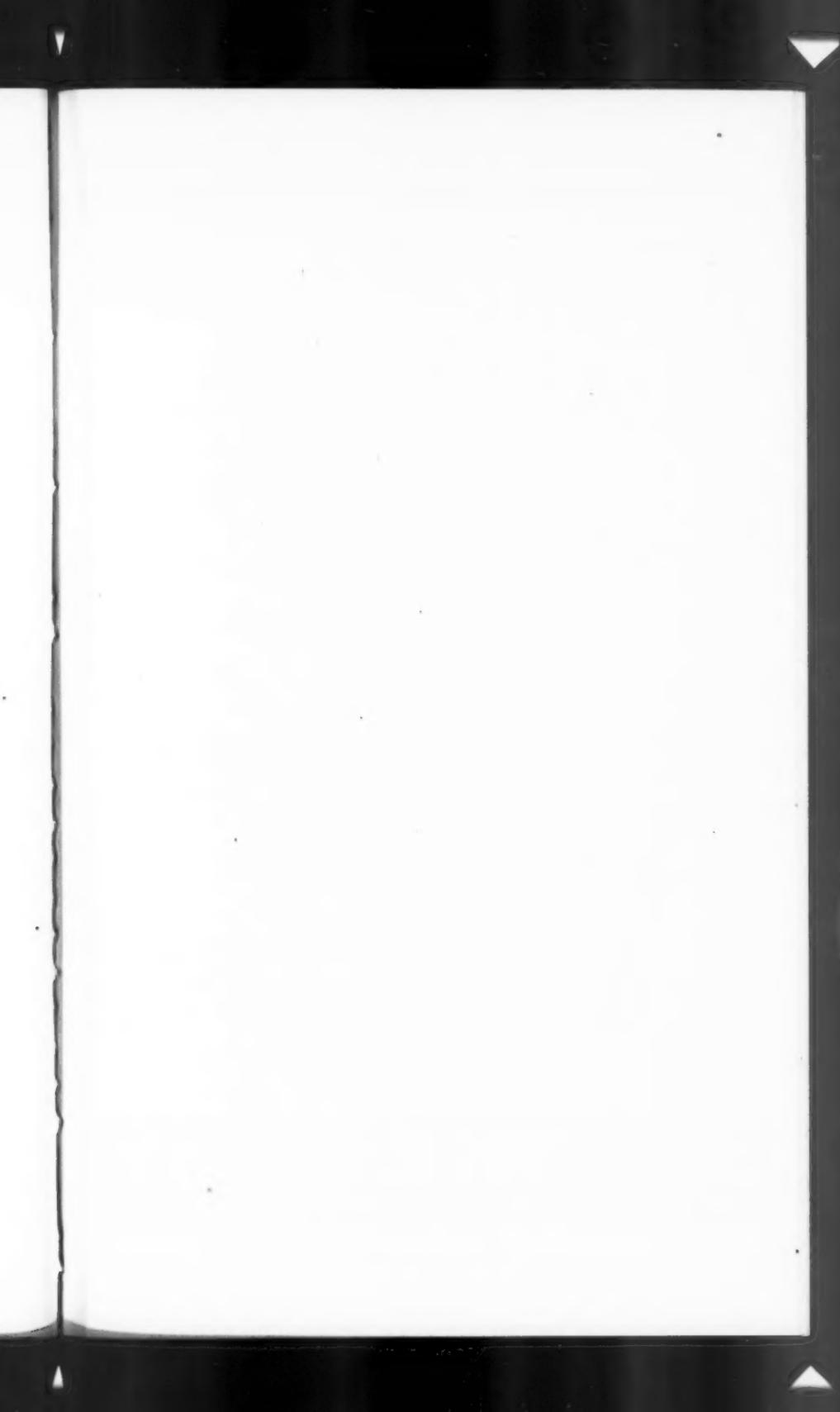
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MAZAK's castability is combined with great strength. Because MAZAK is based on 'Crown Special' Zinc of 99.99 + % purity, inter-crystalline corrosion — causing distortion and disintegration — has been banished. Every batch of MAZAK is spectrographically examined.

Other advantages include high tensile and impact strength; ductility; durability; corrosion-resistance; low finishing cost and ease of plating. When such qualities are essential, use or specify MAZAK alloy, which provides the optimum combination.

MAZAK

IMPERIAL SMEILING CORPORATION (SALES) LTD. 37 DOVER ST. LONDON W.1



HIS ALL-ROUND EXPERIENCE—

— WITH HOOVER F.H.P. MOTORS

TRADE MARK

***will help your plans
for increasing
customer satisfaction***

He is a Hoover Technical Representative; he spends his time dealing with F.H.P. motors. Naturally, therefore, he has a store of sound, practical advice on all kinds of F.H.P. problems. Behind him, too, stands the world-wide Hoover

organisation with its vast accumulation of research and technical knowledge and engineering experience. Why not arrange for this man to call and discuss your future plans. He may be able to give you much valuable information that will lead to still GREATER CUSTOMER GOODWILL towards your own products. Write to :—

HOOVER LIMITED

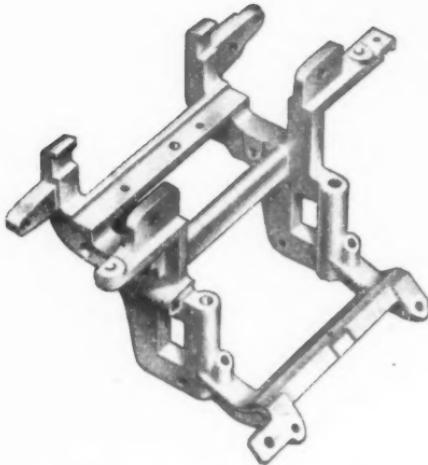
INDUSTRIAL PRODUCTS DEPT. • PERIVALE • GREENFORD • MIDDLESEX



W. E. SYKES LTD · STAINES · MIDDX · Phone: Staines 978 9 · Grams: "Sykutter," Staines

**They're talking
again about
PRESSURE
DIE-CASTINGS**

**This time
it's about
BRACKETS**



ALL HOLES AND DIMENSIONS CAST TO CLOSE LIMITS WHEN REQUIRED

WOLVERHAMPTON DIE-CASTING CO. LTD.
GRAISELEY HILL WORKS · WOLVERHAMPTON.

HE CAN BE THE VILLAIN



ON A GOOD PRODUCTION LINE !

One cutter in need of attention can impair your whole production line. Install a Cincinnati No. 2 Cutter and Tool Grinder in your toolroom and ensure that your cutters are maintained correctly sharpened.



★ Correctly sharpened cutters mean better finish, permitting machining to finer limits and improved quality of finished product.

★ Correctly sharpened cutters achieve a reduction in cost through more pieces per grind and more re-grinds possible per cutter.

CINCINNATI

No. 2 CUTTER & TOOL GRINDER

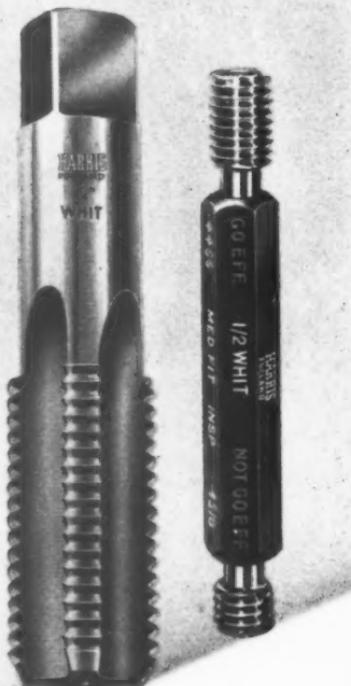
CINCINNATI MILLING MACHINES LTD., TYBURN, BIRMINGHAM, 24

Sales Representatives for Great Britain and Northern Ireland: Charles Churchill & Co. Ltd., Coventry Road, South Yardley, Birmingham, 25.

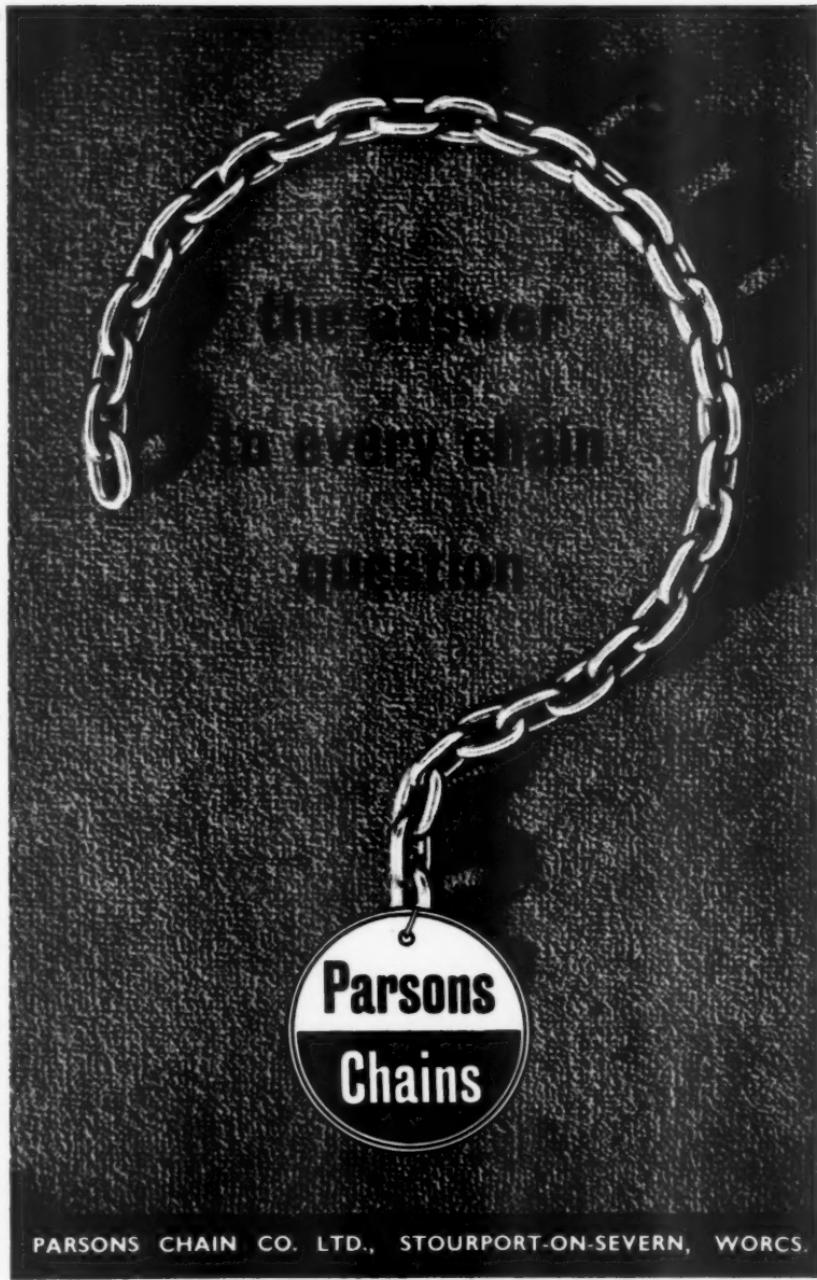
Sales Representatives for Eire: Booth Bros. Ltd., Dublin.

HARRIS

GAUGES,
Ground Thread
TAPS and DIES



JOHN HARRIS TOOLS LTD. · · WARWICK · · phone 741 (4 lines)



Excuse our enthusiasm
but to us
these
parts are
greater than



SOMEWHERE in Africa a dusky cyclist, caught by nightfall, goes his homeward way; somewhere in Berkshire a parson rides back from choir practice under the English stars. And both need these zinc alloy die castings — parts of a cycle dynamo for home and export markets.

Why these parts are die cast in zinc alloy

Zinc alloy is non-magnetic, and can be cast to fine limits to fit closely round the essential mechanism and ensure a snug fit between the halves of the dynamo. A phosphate treatment before enamelling ensures that the finish will adhere firmly and withstand weather and road dirt. The assembled dynamo is very robust, and the two-cavity dies used are still going strong after 1½ million impressions.

Other uses for the transport industry

Bicycle parts made by zinc alloy die casting include bells, sprocket wheels, carrier parts and lamp brackets. Parts made by this process are also used in motor cycles, cars, lorries and other vehicles.

Some facts about zinc alloy die casting

Speed is the essence of the die casting process — the shortest distance between

* Photograph by courtesy of Joseph Lucas Ltd.

raw material and finished product. Zinc alloys are the most widely used metals for die casting because they ensure :

STRENGTH: Good mechanical properties for stressed components.

ACCURACY: Castings practically to finished dimensions, little or no machining.

STABILITY: Close tolerances maintained throughout the life of the casting.

Hence the widespread wartime use of zinc alloy die casting for gun sights, periscopes, tank carburettors, etc.

British Standard 1004

Alloys conforming to B.S.1004 should be specified where strength, accuracy and stability are essential.

ZADCA

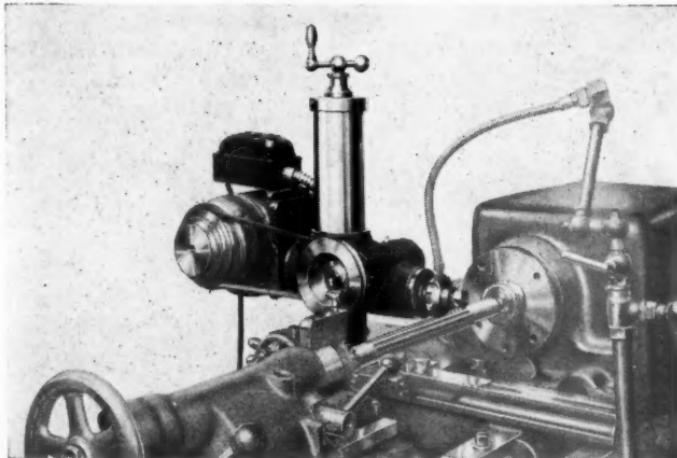
ZINC ALLOY DIE CASTERS ASSOCIATION
LINCOLN HOUSE, TURL STREET, OXFORD.
TELEPHONE: 48088.

ZINC ALLOY DIE CASTINGS PLAY AN IMPORTANT PART IN THE EXPORT MARKET

Enquiries about the uses of zinc alloy die castings are welcome. Publications and a list of Members will be sent on request.

cut costs WITH **AJAX**

MOTORISED UNIVERSAL MACHINE TOOL



Bench mounting or Conversion of Lathes and other Machine Tools



Surface Grinding



Brake Drum and Internal Grinding



Thread and Worm Grinding



Hob Grinding



Slitting



Side Mill Grinding



Cylindrical Grinding



Cutter grinding with cup wheel



Milling

Grinding after chrome plating, End Milling, Spur Gear Cutting, Straight and Woodruff Keyway Cutting, Spline Milling and numerous other processes—all to precision limits, using interchangeable heads.

AJAX

AJAX MACHINE TOOL COMPANY LTD.
WESTMOUNT WORKS, HALIFAX, YORKSHIRE, ENGLAND.



HARPER ROAD WYTHENSHAWE · MANCHESTER
PHONE: WYTHENSHAWE 2215. GRAMS PNEUTOOLS. PHONE

*We can now
accept your enquiries
for*

JIGS · FIXTURES & GAUGES

PRESS TOOLS · MOULDS AND
SPECIAL PURPOSE MACHINES

of all kinds

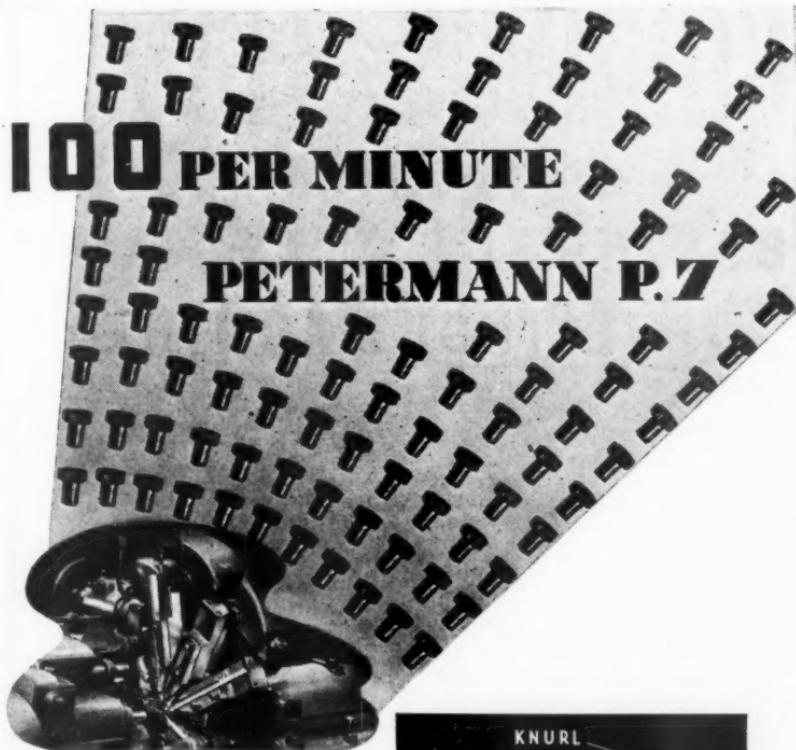


Up-to-date shops specially laid out and equipped for making, on a production basis, every type of precision ground gauges; limit snap, form, calliper, taper and special purpose gauge, as well as jigs and fixtures of all kinds, press tools, moulds and special purpose machines. Highest class workmanship and accuracy guaranteed.

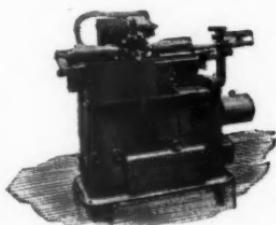
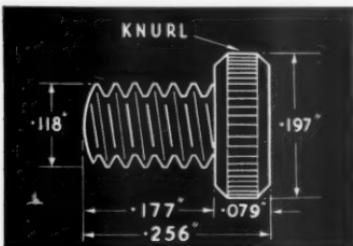
G.P.A. TOOLS & GAUGES LIMITED

G u a r a n t e e d P r e c i s i o n A c c u r a c y

Members of the Gauge & Tool Makers' Association



This typical example of high production demonstrates the capabilities of Petermann P.7 Automatic Machines. Similar phenomenal production times are constantly achieved on all machines in the Petermann range for a large variety of small repetition parts. Our Petermann Specialists are always at your service.



**CHARLES CHURCHILL
& CO. LTD.**

COVENTRY ROAD, SOUTH YARDLEY, BIRMINGHAM, 25

Also at LONDON, MANCHESTER, GLASGOW, and NEWCASTLE-ON-TYNE

GIDDINGS & LEWIS

HORIZONTAL

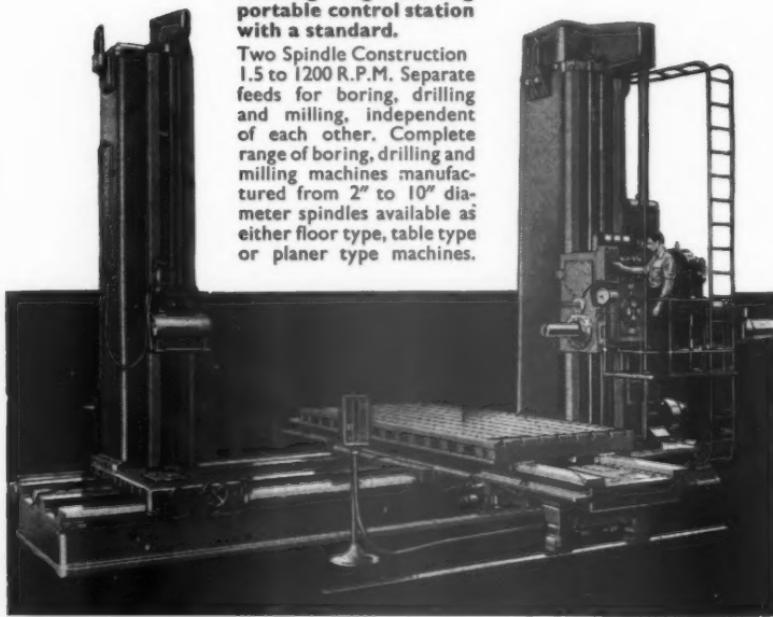
BORING • DRILLING AND

MILLING MACHINE

570 T
TABLE TYPE

machine with extra large working range showing portable control station with a standard.

Two Spindle Construction 1.5 to 1200 R.P.M. Separate feeds for boring, drilling and milling, independent of each other. Complete range of boring, drilling and milling machines manufactured from 2" to 10" diameter spindles available as either floor type, table type or planer type machines.



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ROCKWELL
MACHINE TOOL CO. LTD.

ROCKWELL HOUSE, SECOND WAY, EXHIBITION GROUNDS, WEMBLEY, MIDDX. Phone: Wembley 6353



Single-Spindle Automatic Screw Machines.
Multi-Spindle Automatic Bar Machines.
Single-Spindle Automatic Chucking Machines.
Multi-Tool Production Lathes.
High-Speed Precision Lathes.
Centreless Grinding Machines.
Lapping and Honing Machines.

General Catalogue
on request.

Broaches,
Milling Cutters,
Twist Drills, Centre Drills,
Reamers, Adjustable Reamers
Drill-Reamers, Cut Thread &
Ground Thread Taps, Tap
Wrenches, Dies, Die Stocks,
Dieheads, Sleeves & Sockets,
Quick-Change Drill Chucks,
Lathe Chucks, Machine Vices,
Coolant Pumps, Hacksaw
Blades, Files and Rasps, etc.

BSA **SMALL TOOLS**
AND **MACHINE TOOLS**



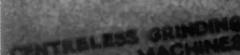
*The range
includes—*



SINGLE-SPINDLE
AUTOMATIC CHUCKING
MACHINES



MULTI-TOOL LATHES



CENTRELESS GRINDING
MACHINES



SINGLE-SPINDLE
AUTOMATIC
SCREW MACHINES
and others

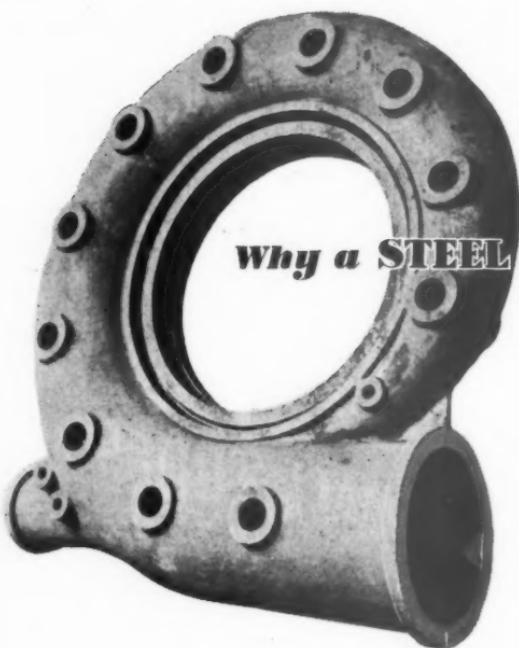
B.S.A. TOOLS LIMITED · BIRMINGHAM · ENGLAND.

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BRANCHES: LONDON · MANCHESTER · LEEDS · BRISTOL · CARDIFF · NOTTINGHAM · GLASGOW · BELFAST



Why a STEEL CASTING?...

this question is asked, and with this exception answered, in each of this series of advertisements which demonstrate for the interest of engineers and designers the range, and the variety of components large and small, which are produced in the steel foundries to-day. It is felt, however, that to explain to an engineer or a designer why this particular *Spiral Casing* for the new *Loch Sloy Hydro-electric Power Plant* is a steel casting would be to state that which is obvious. The engineer and the designer will be chiefly interested in the fact that it was produced at all in this form, for it is the first time that a large *Spiral Casing* has been produced in this country as a single unit. The casing was originally designed for production in two parts,

but there were important advantages to be gained by producing it as a single casting; it was therefore re-designed after consultation with the steelfounder, and duly cast in one piece.

Through these *Spiral Casings*, water is supplied to a reaction-type water turbine, the output of which is 45,500 h.p. and the head of water is 912 feet. Each steel casting must conform exactly to the requirements of the designers, the English Electric Company Limited, and before delivery each casting is pressure tested to 740 lbs. p.s.i.

The weight of each finished casting is 40 tons and the overall extreme diameter is 20 feet 9 $\frac{1}{2}$ inches; in the small illustration the *Spiral Casing* is shown in relation to the size of a man of average height.



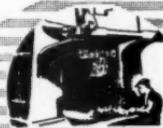
You can make wider use of steel castings...

The Secretaries, British Steel Founders' Association, 381 Glossop Road, Sheffield.



Is your problem here...

A DIE WEAR (FORGING)



B DRY LUBRICATION



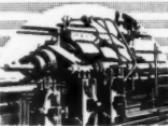
C RUNNING-IN SEIZURE



D SCREW THREAD SEIZURE



E HIGH TEMPERATURE LUBRICATION



F DIE WEAR (EXTRUSION)

Lubricating problems caused by heat, pressure or low running speeds are solved by 'dag' colloidal graphite — the finest possible form of graphite for all industrial purposes.

dag
COLLOIDAL GRAPHITE
Graphite at its finest!



To : ACHESON COLLOIDS LIMITED
9 Gayfere Street, London, S.W.1.

Please send me literature on solving the following lubricating problems with 'dag' colloidal graphite : (Please tick items required — see above) **A B C D E F**

Name

Address

2324



The Sturdy KENT-OWENS HAND MILLER

BALANCED head mounted on two steel posts ensures chatter-free operation. Head is counter-balanced by an adjustable coil spring. Table hand lever is readily changed from front to rear, similarly the head lever can be set for either front or rear operation, both levers are adjustable for length.

Table 25" x 9" - Table Travel 10" - Table Travel for 180° of Hand Lever 4 $\frac{1}{2}$ " - Vertical Feed of Head by Lever 4" - Total Head Movement 7" - Cross Adjustment 2 $\frac{1}{2}$ "
Spindle Speeds 20 - 1666 R.P.M.



IN STOCK

COMPLETE WITH SPINDLE MOTOR,
SUDS PUMP and ARBOR.



INSPECTION IN LONDON OR WILL
SEND ON APPROVAL.



Also available with Hand Movement to Table
Only, in which case Head has Micrometer
Adjustment of 7".



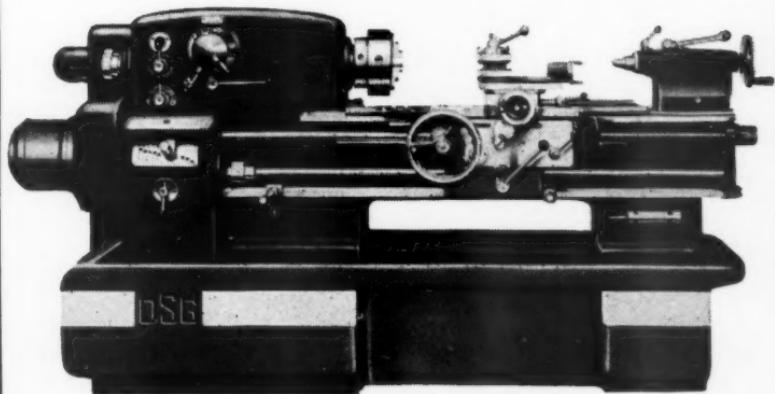
CATMUR MACHINE TOOL CORPORATION LTD.

WHITEHEAD HOUSE, 247-9 Vauxhall Bridge Rd., LONDON, S.W.1

Telephone : WHitehall 0094-5 (Extn. 4 Mr. Langley)

For High Class Production
or Toolroom Work

TYPE 13



13" SWING PRECISION LATHE.

from our
New Range
13" to 30" Swing

Flanged Vee Rope Motor Drive
Self-Adjusting Clutch
Middle Bearing to Spindle
Final Drive to Spindle by Vee Ropes
Patent "Fastlock" Spindle Nose
Wide Range of 12 Spindle Speeds
Wide Range of Threads

CATALOGUE and
PARTICULARS on request



DAWSON

CUTTING PRODUCTION COSTS

This Dawson machine is washing, rinsing and drying thousands of aluminium and steel containers every day—saving time, labour and costs and allowing a steady flow of work without pause or bottleneck in the production line.

Dawson Metal Parts Cleaning and Degreasing machines are in operation in all kinds of engineering works, cleaning everything from small nuts and bolts to complete aero engines and motor buses.

METAL PARTS CLEANING *and* DEGREASING PLANT



Manufactured by DAWSON BROS. LTD., GOMERSAL, LEEDS.

Sole Distributors & Consultants :

DRUMMOND-ASQUITH (SALES) LTD.

King Edward House, New Street, Birmingham.

OPERATION
OPERATION
OPERATION
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OPERATION

THOSE EXTRA
OPERATIONS
CAN OFTEN BE
ELIMINATED
BY THE USE OF
CLOSE LIMIT

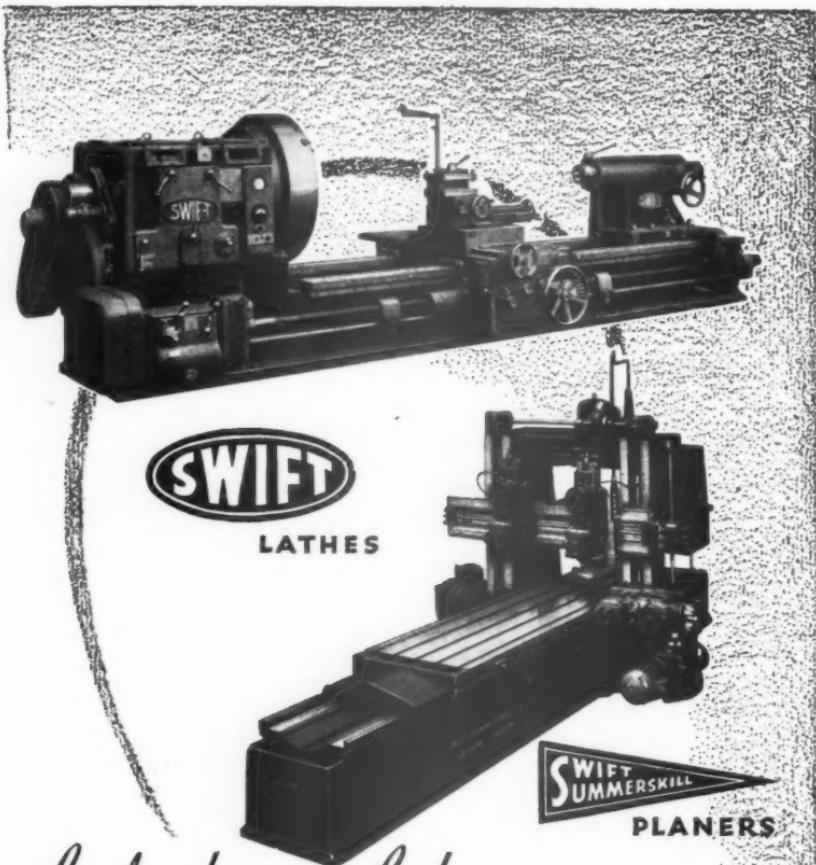
Brass & Bronze EXTRUSIONS



McKECHNIE BROTHERS, LTD.

Metal Works: Rotton Park Street, Birmingham, 16
 Copper Sulphate & Lithopone Works: Widnes, Lancs.
 South African Works: McKECHNIE BROTHERS S.A. (PTY.) LTD.,
 P. O. Box 382, Germiston, S.A.

Branch Offices:
 London, Leeds, Manchester, Newcastle-on-Tyne

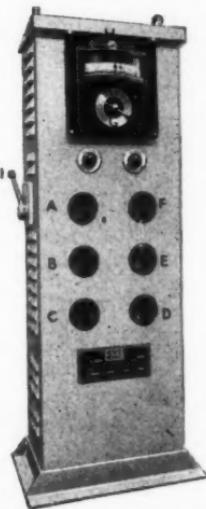
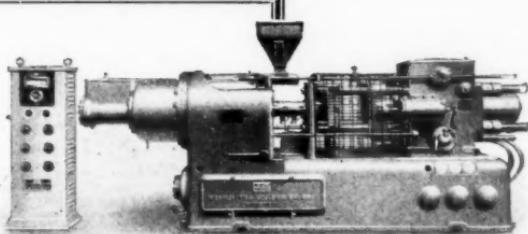


*Leadership in Lathes
Perfection in Planers*

SWIFT LATHES are built as both Centre Lathes and Surfacing and Boring Lathes, and range from 17in. swing to 72in. swing, with any length desired between centres.

SWIFT-SUMMERSKILL PLANING MACHINES are built from 2ft. 6in. square up to 6ft. 6in. square, of any length of table up to 40ft. 6in., of both Double Column and Openside types, with either all Electric or reversing Two Belt Drive. Special All Electric Feed Motion.

GEO. SWIFT & SON LTD.
CLAREMONT WORKS • HALIFAX • ENGLAND



A Control dial **F** Nozzle heater dial
B Rear heater dial **G** Selector dial
C Rear centre heater dial **H** Red pointer adjustment
D Front centre heater dial **I** Isolator switch
E Front heater dial

Automatic Temperature Control

Cylinder has a large heating capacity with 5 A.C. heating units. Heater switching control for maintaining working temperature is entirely automatic. When first switched on all heaters automatically give full capacity. When working temperature is reached they are automatically switched to proportional heating as set by dial for various positions along cylinder. At maximum working temperature heaters are switched off automatically and switched on again when temperature falls.

E.M.B. Patent No. 9B INJECTION MOULDER

FEATURES

- ★ Temperature automatically controlled
- ★ Controllable heating zone
- ★ Single handle operation
- ★ Interlocked handle gives correct sequence
- ★ Timed injection cycle prevents "scamped" mouldings
- ★ Dies have 136 tons direct lock — no toggles to wear or jam
- ★ Automatic attachment available as an extra
- ★ Interlocked sliding gate guard
- ★ All air cylinders and rams are hard chromium plated

CAPACITY

Plasticising capacity:—

4 oz. cyl.: 34 lb/hr cell. acet.
2 oz. cyl.: 26 lb/hr cell. acet.

Distance between bars $11\frac{1}{2}$ " \times 10"

Max. and min. die thickness 12"-2"

Movement of die platens $7\frac{1}{2}$ "

Max. area of work at 7 tons/sq. in.: 36 sq. in.

Locking force 136 tons

Injection pressure: 4 oz. cyl.: 7.6 tons/sq. in.

2 oz. cyl.: 11.9 tons/sq. in.

E.M.B. CO. LTD
WEST BROMWICH — ENGLAND

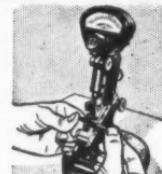
Johansson

ground thread taps



JOHANSSON TAPS are now in full production again in this country—which means that their unequalled accuracy and performance are once again at the service of your production.

May we send you details of some of the extraordinary performance figures Johansson Taps are putting up now in famous British factories?



Johansson design, Johansson heat treatment and Johansson precision production are the three secrets of Johansson Tap supremacy. Descriptive folder gladly sent on request.

CE **JOHANSSON LTD.**

PRECISION TOOLS AND INSTRUMENTS

SOUTHFIELDS ROAD, DUNSTABLE, BEDS.
Tel. Dunstable 422/3.

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2. E. M. Barnes, 162 Church Lane, Birmingham 20.
3. Henry Osborn Ltd., 26-28 Dean Street, Newcastle-on-Tyne, 1.
Tel. 20311.
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Glasgow, C.1. Tel. Central 2251.



DHB

Stellite Drills
FOR HARDENED STEEL
Remove
BROKEN TAPS
WITHOUT
ANNEALING



SIMPLY
DRILL
OUT

DELORO STELLITE

TOOL BITS • PRECISION CASTINGS

DELORO STELLITE drills have been specially developed for
drilling steels harder than Rockwell C.51, Brinell 500 or
Vickers 560. Send for leaflet B.19.

DELORO STELLITE LIMITED, HIGHLANDS ROAD, SHIRLEY

TELEPHONE:
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TELEGRAMS:
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• MILLING CUTTER BLADES • TIPPED TOOLS • WORKRESTS

HARDFACING RODS • TOOL TIPS

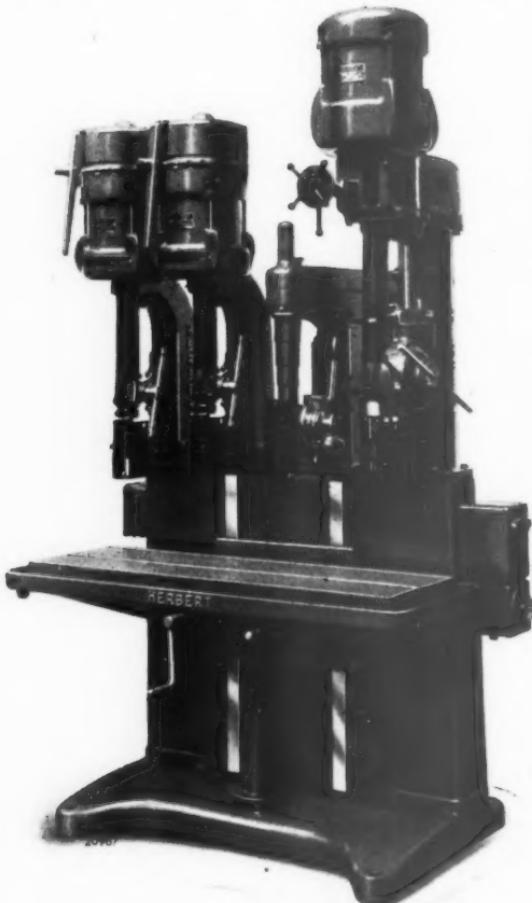


HERBERT



HERBERT ALL-ELECTRIC DRILLS

A complete range, operated on A.C. or D.C. voltage, for drilling and tapping from the smallest holes up to $1\frac{1}{2}$ in. diameter. Made with 1, 2, 3, 4 or 6 spindles, either column or bench type. Speeds up to 18,000 r.p.m.



A combination of top columns—two Type V Juniors, one Type H and one Type V—mounted on a single base.

Features include: finger-tip control, instantaneous starting, stopping and reversing of spindles, instantaneous speed changes; all spindles efficiently guarded by telescopic guards.

Machines are supplied suitable for either general purpose or manufacturing work.

Unit construction enables different types of top columns to be mounted on the same base, providing an exceptionally wide speed range on the same machine.

*Full particulars
on request.*

**EARLY
DELIVERY**

ALFRED HERBERT LTD · COVENTRY

AH — **HERBERT** — **AH****CUTTING DIFFICULT THREADS QUICKLY**

The new HERBERT HOLOZONE DIES are proving very satisfactory in cutting ACME and other coarse pitch, deep threads, single or multiple start, with helix angles up to 20° or more; also for threading thin-walled tubes, or other work which usually chatters and gives trouble.

We will gladly quote for dies for dealing with any parts of which samples or sketches are submitted.

ALFRED HERBERT LTD • COVENTRY



THE SCREW WITH A *Head* START!



Each Phillips Screw or Bolt has a precision forged head recess accurately fitted by the matching driver bit. The recess is a special four-winged shape with tapering sides, which automatically centres, grips and aligns the driver, and is proportioned to allow maximum driving torque for each size of Bolt or Screw. Phillips Screws and Bolts are ideal for power driving. The heads do not burr, costly driver skids are eliminated and assembly is faster. They are made with Round, Mash, Countersunk, Oval or Fillister Heads in all sizes from 6 B.A. up to $\frac{1}{2}$ " diameter by LINREAD LTD., Sterling Works, Cox Street, Birmingham, 3, who will be pleased to forward further information on request.



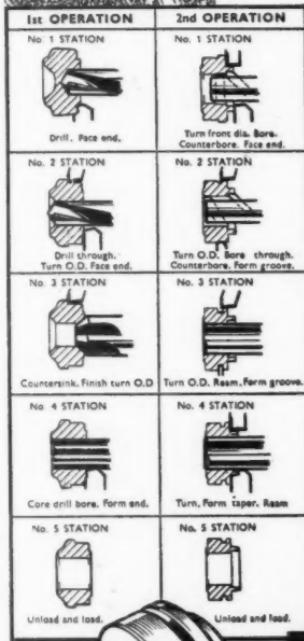
Linread Phillips Screws

LINREAD LIMITED COX STREET BIRMINGHAM 3

and at...
CLIFTON HOUSE, EUSTON ROAD, LONDON, N.W.1

When writing, please mention department I.P.E.

MULTI-SPINDLE Automatics for fast production of long or short runs and No Cams To Change



Here's a typical example of production on the Wickman 6" Multi-Spindle Chucking Automatic, demonstrating the high output potential and cost cutting advantages of this range of machines. The 3½ Nc. Chr. C.H. Steel Gear Blank forging shown below is completely machined in two operation cycles of 32 seconds each, change-over between first and second operations being completed by one operator in under 2½ hours because there are no cams to change.

The Wickman patent Autosetting Mechanism dispenses entirely with costly interchangeable cams; all feed strokes are adjusted by means of an Allen key in five minutes or less.

Higher productivity demands an examination of the Wickman Multi-Spindle Automatic range. It comprises 4", 5", 6" and 8" Bar Machines; 5" and 6" Chucking Machines. Write to the Wickman Technical Publications Department for Catalogue W.60.



Wickman
for



3½ Nc. Chr.
C.H. Steel Gear
Blank Forging.
Finish machined
at a nett pro-
duction rate of
90 per hour.

A. C. WICKMAN LIMITED
COVENTRY · ENGLAND

Production

TO Production Engineers

Q

How can output be increased on semi-obsolete machines which cannot be replaced?

A

If you can't improve machining time you can at least improve handling time. By the use of Enots Air Clamp Pneumatic Equipment floor to floor time can be substantially reduced.



The number of manufacturing concerns who have increased output by installing Enots Air Clamp Pneumatic Equipment runs well into four figures. Here are a few users:

The Austin Motor Co. Ltd.

B.S.A. Cycles Ltd.

The General Electric Company Limited.

The Hercules Cycle & Motor Co. Ltd.

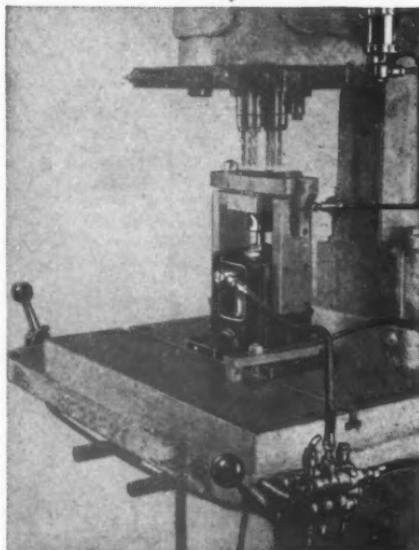
J. & H. McLaren Ltd.

The Standard Motor Co. Ltd.

The WIPAC Group

Why not write for literature?

BENTON & STONE LTD., ASTON BROOK STREET, BIRMINGHAM 6

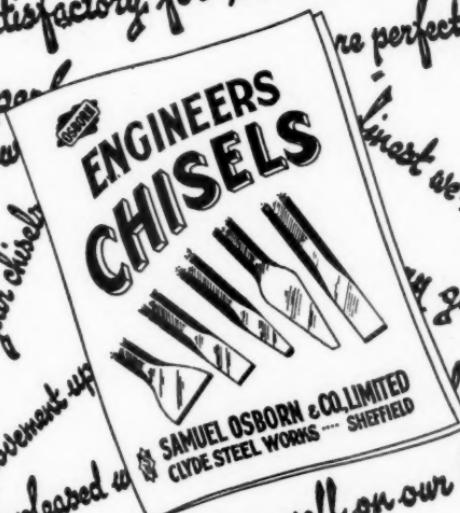


Enots

**AIRCLAMP
PNEUMATIC
EQUIPMENT**

" - apparent that your chisels are the best."
 " - quite satisfactory for stainless welding."
 " Excellent price."
 " Successful use."
 " delighted with your chisels."
 " improvement up."
 " very pleased with."
 " doing well on our hard castings."
 " better than anything we have previously used."
 " stood up very well on Thermic welding."

" are perfectly satisfied."
 " finest we have ever had."
 " good results."
 " be performance."



The quotations are extracts from the many letters of commendation received from customers all over the world

It will pay you to try a sample chisel. Send us the size and shape most suitable and we will send you one on sale or return.

A copy of our leaflet on Engineers Chisels sent free on application to :

DEPT. J.G.3.



SAMUEL OSBORN & CO. LTD
CLYDE STEEL WORKS, SHEFFIELD





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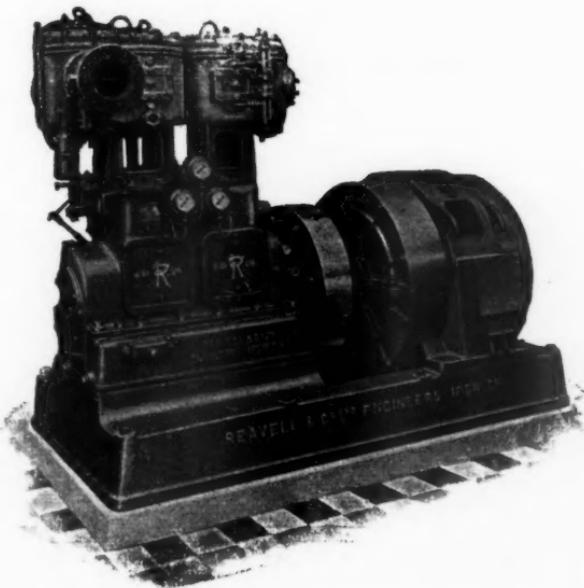
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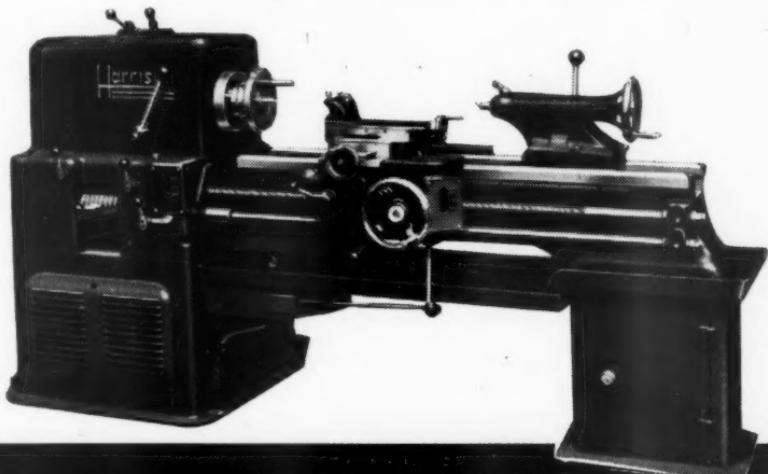
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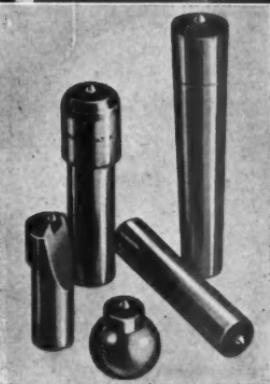
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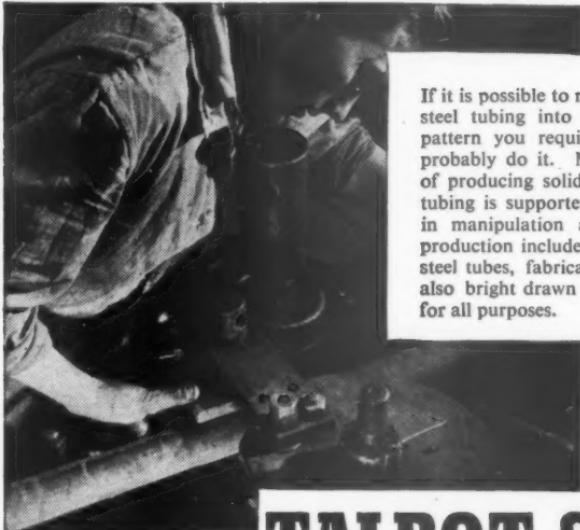
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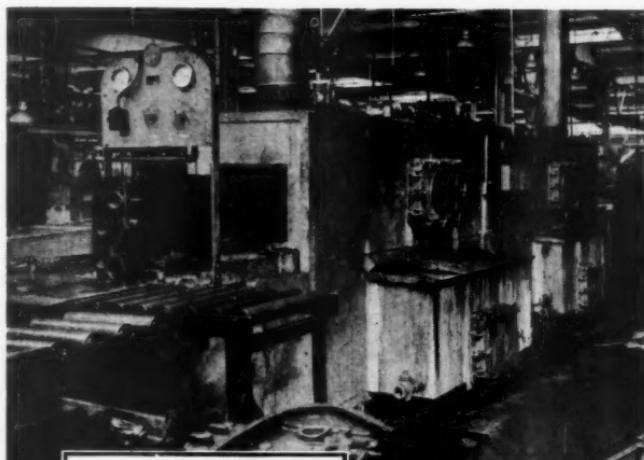
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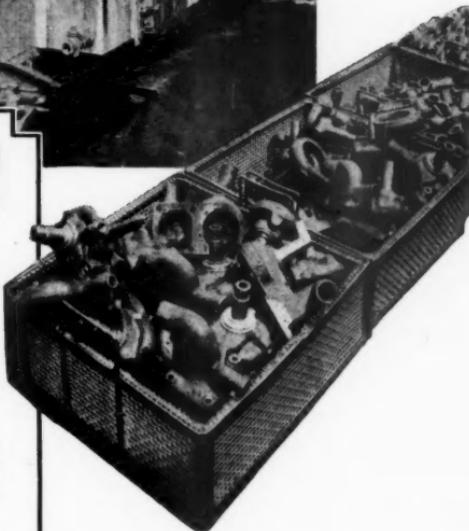
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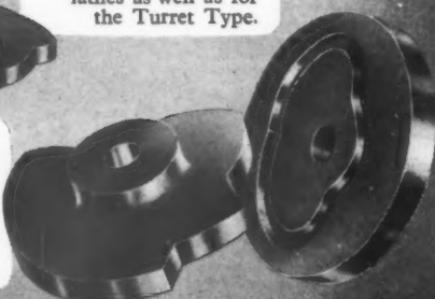
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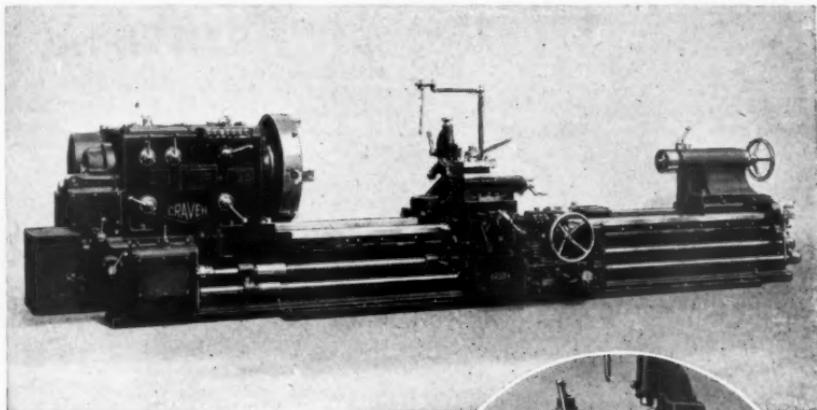


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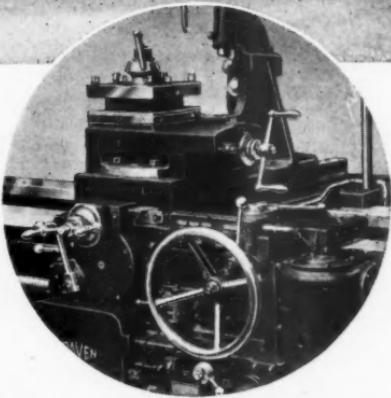
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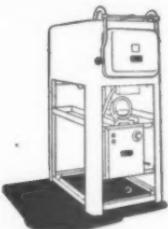


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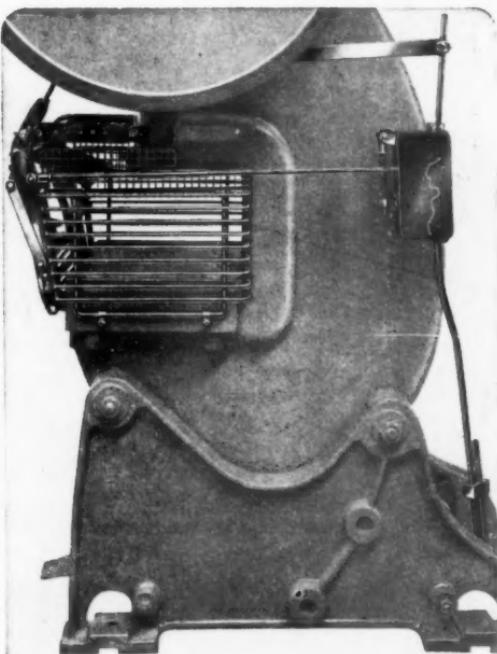
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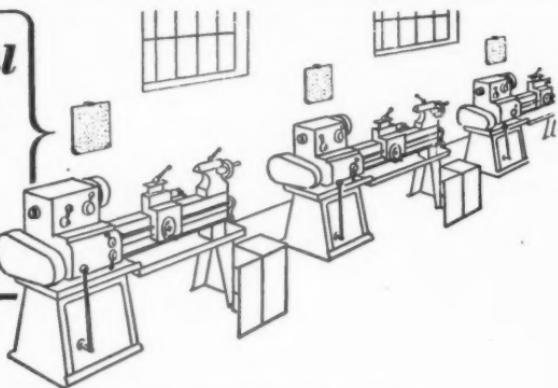
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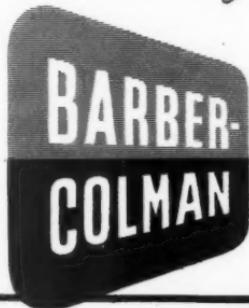
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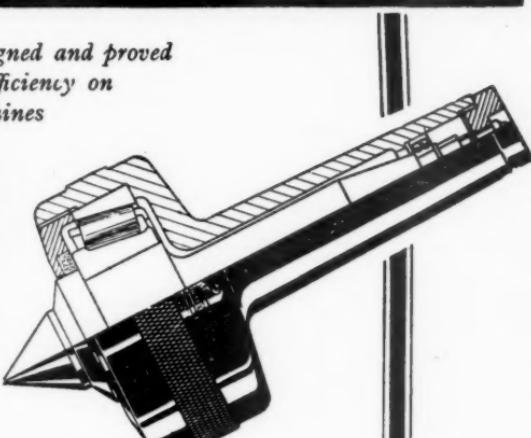
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inside or outside trigger, and usual snaps.



Rotogrinds—suitable for internal grinding,
cleaning castings, etc. The range includes
precision grinding and heavy-duty types.
"Straight" and "grip" handles available.



Pneumatic Hammer for chipping and caulking.
Weight from $7\frac{1}{4}$ lb. to $13\frac{1}{2}$ lb.

The sensitive throttle which is an exclusive feature of all HOLMAN PNEUMATIC HAMMERS gives the operator exact control — from light taps to full-force blows. Every Holman Hammer is a fast, powerful, robust and handy tool in which vibration and air consumption are reduced to a minimum. The range includes chipping and riveting hammers of various types and sizes, and specialist advice will always be given as to the best hammer for any particular job.

*The first name
for lasting service*

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